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A special chemistry course was designed and written for the nonscience major or non collegebound secondary school student. Both the textbook and the laboratory manual were field tested in two small rural schools of southwestern New Mexico; students from four similar schools served as controls. Student populations involved were of mixed ethnic groups. Pretest results showed that the experimental group students started at significantly lower ability levels in reading, verbal reasoning, abstract reasoning, numerical ability, and chemical knowledge. Despite this starting position, the experimental group made substantial gains on the standardized chemistry test, and almost doubled the gains made by the control group on a special chemistry test. A possible predictive factor for success in chemistry may be indicated based on correlations obtained. (BC)

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FINAL REPORT
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A SMALL PROJECT RESEARCH PROPOSAL IN SECONDARY SCHOOL SCIENCE EDUCATION

August 1968

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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A SMALL PROJECT RESEARCH PROPOSAL IN SECONDARY SCHOOL SCIENCE EDUCATION

George Walton, Ph.D.

Western New Mexico University

Silver City, New Mexico

August 30, 1968

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INTRODUCTORY SECTION

SUMMARY

During the past decade or two enrollment in high school science courses, including chemistry, has steadily declined.[1] This trend is the outgrowth of several factors. For example, the great explosion in technology of the past twenty years has introduced a body of knowledge which is substantially too large for one year of study. The increased knowledge has also led teachers to stiffen the requirements of the course. As the course work became more difficult, competition for grades has increased and specialization has set in. Today students of moderate or low ability tend to shun chemistry, and even high caliber college-bound students shy away from this subject unless they intend to major in a science field.

On the other hand, the increased technology makes it necessary that every citizen have a fundamental knowledge of chemistry in order to interpret and cope with today's world.

As an answer to the problem of dwindling enrollment, and to supply the lack of a suitable course for the average student, this Investigator proposed that a different kind of chemistry course be devised. This course would aim to provide the student with a fundamental knowledge of chemistry so that as a citizen he could understand and cope with today's and tomorrow's world on a more knowledgable basis. To have value for the average student, rather than for the science major or college-bound, the standards in the course, the content, and the textual materials would all have to be developed in terms of the average student.

Such a special course was written and field tested during the academic year 1967-68 in the following manner:

1. Two small rural schools in southwestern New Mexico offered the special course to twenty students comprising the Experimental Group. In one of these schools, the regular course was offered also. Students were not informed regarding the offering of the special course until enrollment was closed for the regular course. Thus students in the experimental course were those who would not have taken chemistry normally.

2. Students taking the regular chemistry course in four high schools of the same geographical area comprised the Control Group of 52 students.

3. All of the 72 students were pre-tested using a standardized chemistry test (Anderson-Fisk) and a special chemistry test drawn to measure the objectives of the special

course. They also were given the Differential Aptitude Tests (Form L, Psychological Testing Corporation) and a test for reading ability (Nelson-Denny). Schools were asked to submit grades for these students in English, Mathematics, and Science as of September, 1967, as well as the final grades made in chemistry.

4. Each of the students was post-tested with another form of the Anderson-Fisk test, and with the Special Chemistry test.

Analysis of the pre-tests revealed that students enrolled in the Special course had less ability in all categories tested. The data on reading ability was considered especially significant because students in the Experimental Group were on the average more than two grade levels below the Control Group. On the basis of this finding, all textual material was submitted to a reading specialist for analysis so that the reading level could be designed to fall within the reading level of the Experimental Group. While one of the objectives had been to design a course with a low enough reading level so that any of the Experimental Group students could handle it, this task was found to be a practical impossibility since the lowest level of student reading ability was less than Grade 7. In general, every effort was made to hold the reading level of textual material to the lowest practical level.

Considering the gap in initial abilities, the Experimental Group students accomplished a gain (67.1%) comparable to that of the Control Group (66.8%). The Control Group students achieved an average very close to that of the national average on the Anderson-Fisk post-test. This fact would indicate that the level of instruction in the small rural schools of this study is comparable with that offered to students in large urban centers.

The data regarding the Special Chemistry test was quite revealing. While the actual gain made by students in the Experimental Group was higher than for the Anderson-Fisk test, the percent of gain was less because of higher initial scores. On the other hand the Control Group students made a smaller amount gain, and the percent of gain was only a little more than half as great as made by the Experimental Group. Since the Control Group had initially made a higher grade on the Special test, this finding would tend to indicate that the objectives of the Special course were being attained if the Special test is measuring the objective.

T-test scores were derived in order to determine the statistical significance of differences in the means. In general the t-test scores indicated that there was significance at the 1% level, although gains between the two groups on comparison of the pre-tests and on comparison of the post-tests were greater than the 10% level. Correlations were calculated using the Pearson product moment method. Over one hundred correlations were drawn in an effort to determine the relationship of various factors to achievement in chemistry, both in the Special course and in the regular course. The correlations for the Experimental Group tended to be rather high for reading versus the Special Chemistry pre-test, whereas the Differential Aptitude Tests correlated rather low. The Control Group tended to correlate low on almost all factors in the pre-test. Correlations on post-tests ran much higher, the Experimental Group tending to be higher than the Control Group.

The correlations were analyzed also in an effort to determine whether or not any predictions could be made on the basis of the pre-test scores. This analysis revealed that prediction may be possible since the correlation figures for Experimental students and Control students were almost identical in several cases.

Correlations made for the Experimental Group students in reading ability versus gains on the standardized chemistry test showed a fairly high value ($r = .60$), indicating the necessity for good skill in reading to make a high grade on this test. Similarly, reasonably high correlation values (.50 to .69) were obtained for Verbal Reasoning, Numerical Ability and Abstract Reasoning versus the same gain. This shows that for this standardized instrument students require a fairly high degree of ability in these areas in order to make a high test gain.

The conclusion drawn from this research is that a course has been devised which meets the need of typical high school students as measured by the reading level of textual material, the amount of progress made, and the ability to cope with some of the problems of the modern day world, as measured by the special test developed in this study. Whereas Experimental Group students had made comparable progress with Control Group students on the standardized test, their progress on the special test was almost twice as great. A further indication of the value of such a course is that both of the Experimental schools have requested that it be repeated, and in addition, another three larger schools are planning to initiate the course during the Fall of 1968. During the school year a number of students in one school where both courses were offered asked to be transferred to the Experimental program. (This was not allowed.)

INTRODUCTION

The stated purpose of secondary school education in the United States is to educate students to become useful, well informed citizens. In some areas, particularly in chemistry, there has been a long-term drift away from this objective. The fault lies with the tremendous progress made in this science in the past two decades which requires a constantly enlarging scope and depth of teaching for the science major.

Students who are not science majors or who do not require a chemistry course for a possible college career either disqualify themselves from taking chemistry, or are discouraged from doing so by the teachers or school administrators guiding their programs. A student who is competing for a college scholarship or even admittance is reluctant to take a course which might threaten his overall grade point average.

Our modern world is so largely shaped by chemistry and its by-products that a person can no longer function adequately as a citizen without some knowledge of this discipline. In addition, a knowledge of chemistry can enrich a person's life experience. It can give him a better appreciation and understanding of our common environment. It even can contribute to a sense of greater security; indeed, increased understanding in this field can unlock many doors. More than ever before, the citizen of the future will be called upon to support science socially and politically, to contribute to it, and to interpret, apply, and utilize its results.

Since chemistry is responsible for such a large portion of our everyday life, a knowledge of chemistry potentially can make a student a better dishwasher, a safer gas station attendent, or a better mother. It can confer an increased basis of understanding for almost any task.

Since in general the non-science major and the non-college-bound student will have neither the ability, background, or interest required to take and pass the regular chemistry course, a special course drawn to his ability level and requirements is indicated. This must not be merely a "watered down" version of the regular course, but it must be one specially created to fulfill his stated needs, and to enable the student who takes it to play a more informed and understanding part in society. This study was devised for the purpose of developing such a course.[2]

The hypothesis upon which this research is based assumes that if such a student is presented with a properly designed course, and if he brings sufficient interest and ability to bear upon it, he he will pass the course with grades roughly equivalent to those he makes in other courses. An objective of this study is to impart to the student a degree of knowledge and applicational ability of the science of chemistry so as to encourage the student to apply the methods and approaches of science to other problems in his daily experience.[3]

METHODS

To fulfill the above apparent curriculum lack, this research study included the writing of a chemistry text and laboratory manual for secondary school students who were non-science majors or non-college-bound. The assumption was made that such students would on the average be of lower ability in certain skills. The course was deliberately written to impart a maximum of understanding in the simplest possible manner.[4]

The first problem encountered in the course design was the selection of suitable material. In the interests of brevity, all historical information and all obsolete theory were omitted. Subject matter was treated in considerably less depth than in the regular or traditional chemistry courses; however, deliberate attempts were made to broaden basic understanding by relating concepts to examples chosen from everyday experience.

The course placed teaching emphasis on fundamental concepts and their application. It included some audiovisual materials, particularly as related to concepts difficult to teach, and the inquiry method was used to as great an extent as possible. The course included time, place, and opportunity for a certain amount of re-teaching.

The Special course for this research study was written as simply as possible. Indeed, the attempt was made to write it at the reading level of Grade 7, but this did not prove possible. However, this goal of readability was one kept constantly in mind, and a reading consultant was hired to help with the problem. This Special course also included laboratory work as a very important part of the attempts to attract student interest and involve them to as great an extent as possible. Especially for the student for whom this course would probably be his last scholastic contact with a science course, it was felt desirable to engage all of his five senses to as great an extent as possible in the learning experience. Laboratory work was selected carefully and performed before inclusion in the course. Questions on each Laboratory Unit were designed to be rather open-ended, to stimulate further thought and possible application rather than to call forth cut-and-dried answers.

The next step was to field test this Special course on a pilot basis. This was accomplished starting September 1967 at two small high schools in southwestern New Mexico (Animas and Reserve). For comparison purposes, students enrolled in the regular (or traditional) chemistry courses in four other schools of the same geographical area served as controls. At both Animas and Reserve the teachers giving the Special course were not the regular science teachers; however, they both have credits in chemistry in their background.

Students in both the Experimental and Control Groups were given pre-tests in Reading Ability, Verbal Reasoning, Numerical Ability, Abstract Reasoning, and also in Chemistry (to determine their beginning level of understanding). Two chemistry tests were given; one a special one drawn on the material of this Special course, and one a standardized test in this discipline (the Anderson-Fisk test). Both chemistry tests were also given as post-tests.

An attempt was made to measure interests and attitudes towards course content, teachability, application to other fields, and science in general through personal contact with the students by the Principal Investigator. These contacts showed that these factors would be very difficult to measure by written instrument with any degree of objectivity due to a reluctance on the part of the students in answering questions relating to the above. This reluctance in indicating a degree of interest in the course material, for example, may be due to a desire on the part of the student to avoid giving offense. There was rather general agreement among the Control Group students that the regular chemistry texts were difficult for them to read and understand. And one of the Control schools that started out the regular course with new textbooks abandoned them after five or six weeks in favor of their previous texts.

Another attempt made to measure interest in chemistry on the part of students involved in the field test was through library check outs of associated materials. This was abandoned when it was found that every teacher involved in the field test, both for the Control and Experimental Group students, kept such written material openly available in his classroom or laboratory. Since no written records were kept regarding the use thereof by students, there was no way in which this factor could be considered on a quantitative basis for evaluation.

Details of pre-test procedures were as follows:

1. Nelson-Denny Reading Test for Vocabulary, Comprehension and Rate (Form A). This test was administered to the students

of both groups by Dr. Richard Williams of New Mexico State University (except for a few students who were not present during the initial test period).

2. Differential Aptitude Tests (The Psychological Corporation, New York, 1966, Form L) for Verbal Reasoning, Numerical Ability and Abstract Reasoning. A fourth test, dealing with Clerical Ability, was omitted on the grounds of lack of pertinence. This test was administered as a pre-test by Dr. Robert E. Reilley of the Education Department of Western New Mexico University.

3. The standard Anderson-Fisk Chemistry Test (Form F) for secondary schools. This is a standardized 55 question, multiple choice instrument with published norms on the several types of high school chemistry courses presently being offered. These courses include the Chemical Bond Approach, CHEMSTUDY, and the so-called "regular" or "traditional" course. This test was administered in each school by the teacher giving the standard or Special Chemistry Course and in the presence of the Principal Investigator.

The Anderson-Fisk Test was included so that we might measure the performance of both Experimental and Control Group students using a nationally recognized standard instrument. Supposedly, the Control Group students were exposed in their "traditional" chemistry course to all of the concepts and applications covered by this test, and in depth.

In contrast, the Special Course given to the Experimental Group students was in much lesser depth, and omitted many traditionally taught concepts which were felt to be irrelevant to a citizen's general and useful understanding of the subject.

4. A 40 question, multiple choice test on chemistry in general, but specifically drawn to the text of the Special Chemistry Course of this research study. This test was heavy on non-mathematical applicational questions as shown by the following item analysis:

Applicational type questions	21
Conceptual type questions	13
Factual type questions	6
TOTAL	40

The questions on this test were straight forward, simply expressed, mostly non-mathematical, and based on common examples and problems. A student of any of the current "traditional", CBA, or CHEMSTUDY courses should be capable of making a high score on this test if he has any reasonable grasp of basic chemical knowledge and its application. This test was administered in each school by the teacher giving the regular or Special Chemistry Course and in the presence of the Principal Investigator.

Fairly regular class visits were made by the Principal Investigator, George Walton, during the school year to the classes of both the Experimental and Control Groups. Total visitations to each classroom were approximately eight except for Quemado, where distance permitted only four visits. The visits were made to the Control Groups in order to cancel out the "halo" effect caused by the Principal Investigator's visiting the Experimental Groups. Where it was necessary to make a presentation to classes of the Experimental Group, this was offset by a similar one to classes of the Control Group.

The Principal Investigator constructed tests at 6-week intervals based on the material contained in the Special Course. The 6-week tests were given during the First Semester and consisted of 50 True-False questions covering five chapters each. During the Second Semester each test consisted of 25 multiple choice questions, also covering five chapters. These tests were administered by the teacher who was teaching the Special Course, and aided the teacher in awarding grades to his students.

The Special Chemistry Test and the standard Anderson-Fisk Chemistry Test which were given to both Experimental and Control Groups as pre-tests were also re-administered as end-of-course tests in May, 1968. Teachers in both the Experimental and Control Group utilized the end-of-year test results in awarding student grades for the chemistry courses. The final tests were administered jointly by the course teacher and the Principal Investigator. Proctoring of all the pre- and post-tests was conducted carefully in order to obtain valid test scores.

All of the above pre-tests were administered during the first three or four days at the start of the Fall Semester, 1967 to all students of both the Experimental and Control Groups.

Post-testing: Only the Anderson-Fisk Chemistry Test and the Special Chemistry Test were given as post-tests.

The test data was analyzed first to compare the initial standing of the two groups; secondly to compare their standings at the end of the courses and to calculate the amount and percentage of gains; and thirdly to determine the relationship between various factors. Statistical correlations were run between the various pre-tests, post-tests and "gains". In addition, t-tests were run to determine the statistical validity of differences between the various means.

FINDINGS AND ANALYSIS SECTION

RESULTS AND FINDINGS

Student Populations:

In order to measure the achievement of our research objectives, we have compared the knowledge and applicational ability in the field of chemistry for students taking the Experimental Course with that of a group of Control students enrolled in four high schools of the same geographical area taking the present "regular" course. Due to the small number of students involved in this pilot field study (Experimental, N = 20; Control Group, N = 52), it was decided to accept the total student populations "as is" without any attempt to pair them. In fact, any such attempt would tend to defeat the objectives of this study since the Special Course was devised specifically for that segment of the general student population which was not science oriented, and probably not college bound, regardless of their qualifications.

Therefore, in this research study we would definitely not expect the mental characteristics of the Experimental and Control Group students to be identical. We would, rather, postulate that the "model" student taking the regular chemistry course (Control Group) would be: 1) science oriented 2) of higher average reading ability 3) higher numerical ability 4) good in verbal reasoning and abstract reasoning 5) successful in academic record and background 6) probably college bound.

In contract, our "model" of the student taking this Special Chemistry Course would be one who is: 1) non-science oriented 2) of lower average reading ability 3) lower in numerical ability 4) poorer in verbal reasoning and abstract reasoning 5) normal to subnormal in his academic record 6) probably not college bound. An analysis of the pre-test data has been made to determine whether or not the data confirms our assumptions regarding these two student models.

Several different factors were analyzed to compare the status of the Experimental Group with that of the Control Group as of the beginning of the course. This comparison included ability in Verbal Reasoning, Numerical Ability, Abstract Reasoning (Differential Aptitude Tests), reading ability (Nelson-Denny Reading Test), and knowledgability level in chemistry as measured by a standard chemistry test (Anderson-Fisk) and as measured by a Special Chemistry Test. Results of the t-test are as follows:

DIFFERENTIAL APTITUDE TEST:

	Experimental Group $\bar{X}_1$	Control Group $\bar{X}_2$	$\Delta \bar{X}$	t	A
Total Raw Score	74.500	86.981	12.48	2.382	2%

There is a rather large difference (12.48 points) between the average Differential Aptitude Test scores for the Experimental Group as compared with that for the Control Group. The t-test score shows that this difference in means is significant at the 2% level.

EXPERIMENTAL GROUP

There is a very wide individual variation in the separate parts of the Differential Aptitude Tests. Percentile norms can be obtained by referring to the Test Manual (4th Edition, Section 3) where raw test scores for the individual sections can be converted to percentile norms taking into account sex, grade level, and the semester in which the test is given. Based on these conversion tables, the students of the Experimental Group varied in Verbal Reasoning from the 3rd percentile to the 85th percentile. The range was from the 5th percentile to the 90th percentile in Numerical Ability. The range was from the 5th to the 65th percentile on Abstract Reasoning. The students averaged as follows: Verbal Reasoning 38.7 percentile, Numerical Ability 42.3 percentile, and Abstract Reasoning 30.0 percentile. For the three sections combined the students of the Experimental Group averaged at the 37.0 percentile level.

CONTROL GROUP

Control group students showed a range from the 5th to the 97th percentile in Verbal Reasoning. On Numerical Ability the percentile range was from 10 to 99. The percentile range was from 5 to 95 on Abstract Reasoning. For each section the averages were: Verbal Reasoning 48.9 percentile, Numerical Ability 52.1 percentile, and Abstract Reasoning 44.0 percentile. For the three sections combined the Control Group students averaged at the 48.4 percentile level.

These scores substantiate the postulated difference between the ability levels of the Experimental and Control Groups for Verbal Reasoning, Numerical Ability and Abstract Reasoning. Note that the Control Group students rank fairly close to the national average on this test whereas the Experimental Group students are 13 points below the national average in percentile rank.

The Psychological Testing Corporation has published correlations for Differential Aptitude Test scores as compared with student performance in standard chemistry courses (Test Manual 1966, pages 5-13, 5-14). For the six schools and 209 students involved in their study, the Correlation Factors are:

Verbal Reasoning	.44
Numerical Ability	.63
Abstract Reasoning	.40

Correlations were derived for the gains made on both the Special Chemistry Test and the standard Anderson-Fisk test with the above abilities. These correlations were as follows:

	Experimental Group (N = 20)		Control Group (N = 52)	
	Special Chemistry	Anderson-Fisk	Special Chemistry	Anderson-Fisk
Verbal Reasoning	.10	.69	.33	.33
Numerical Ability	.28	.50	.06	.44
Abstract Reasoning	.13	.51	.21	.49
TOTAL DAT SCORE	.18	.67	.26	.51

It may be noted that for both student groups the correlation values are much lower for the Special Chemistry Test than for the Anderson-Fisk. We believe that this is in part a reflection of the fairly non-mathematical nature of the Special Test, and of the simplicity of the language used in phrasing its questions.

One other marked difference is worthy of note. The correlation between Verbal Reasoning of the Experimental Group gains on the Anderson-Fisk test is over twice as high as for the Control Group, showing a heavy dependence upon this ability for the Experimental Group students.

READING ABILITY:

The assumption that the reading ability of the Experimental Group students was less than that of the Control Group students was rather vividly demonstrated. The "Total Score" on the Nelson-Denny reading test is computed as the sum of the Vocabulary plus twice the Comprehension score (Nelson-Denny Test Manual, page 10). The Experimental Group showed an average of 27 points lower than the Control Group. This difference was statistically valid at less than the 1% level.

Analysis of the data by means of the t-test for uncorrelated data gave:

	Experimental Group $\bar{X}_1$	Control Group $\bar{X}_2$	$\Delta \bar{X}$	t	A
Reading "Total Score"	75.700	102.904	27.204	2.888	<1%

The raw scores obtained from the Nelson-Denny reading test may be converted to Grade Equivalents by means of the "Grade Equivalent Norm Table" (Test Manual, Table 10). The two student groups involved in the field test compared as follows in terms of equivalent grade level:

1. EXPERIMENTAL GROUP

Range: From a low raw score of 7 points equivalent to a reading level of substantially below Grade 7, to a high raw score of 105 equivalent to a reading level of above Grade 14 (both of these extremes are well beyond the normal range of the table as given in the manual).

Average: The average raw score was 48.700. This is equivalent to Grade level 10.0 (entering 10th grade).

Standard Deviation: 21 points. Roughly equivalent to 2.5 grade levels on each side of the average.

2. CONTROL GROUP

Range: this varied from a low raw score of 20 points which was below the range of the table and below a grade equivalent of Grade 7 to a high raw score of 127 points which was well above Grade level 14 (the upper limit of the table).

Average: The average raw score was 66.904 which is equivalent in the table to Grade 12.4.

Standard Deviation: 25 points. One standard deviation on each side of the mean here would range from Grade 9.2 to higher than Grade 14.

Thus the students of the Experimental Group started their course work in September 1967 at a reading level which was equivalent to approximately 2 1/2 grades lower than the Control Group students.

The low and variable reading ability of the Experimental Group students was anticipated. In fact, one objective of this research study was to write this Special course in chemistry at a correspondingly low level of readability. Due to the lack of professional writing ability on the part of the Principal Investigator, the reading level of the course was found to be considerably higher than intended, ranging from Grade 7 to over Grade 19 (as determined by the Gunning-Fogg Index of Readability). Where the the reading level was found to be uncommonly high, a special effort was made to revise the text to a lower level.

The reading level of the Special Course text material does not appear especially detrimental to this research. Mr. Beverly Graham, Science Specialist for the State of New Mexico, personally interrogated each student in the Experimental Group. He specifically asked them whether or not they had any difficulty in reading the course material, and in every case was given a negative answer by the student. In contrast to this, Control Group students reported difficulty in reading their basic text. It may be that the very deliberate and conscious efforts made to express course concepts as simply and plainly as possible resulted in a "readable" text.

Correlations were made between the reading "total scores" and the gains made on both chemistry tests with results as follows:

	Experimental Group	Control Group
Reading "Total Score" versus Special Chemistry Test Gain	.05	.35
Reading "Total Score" versus Anderson-Fisk Gain	.60	.37

From the data it appears that students with below average reading ability (Experimental Group) show no dependence on their gain in knowledge (as measured by the Special Test) upon their ability to read. As measured by the standard test, however, there is obviously a fairly high correlation between test gain and reading ability.

CHEMISTRY TESTS:

1. ANDERSON-FISK: The means obtained for each student group on the Anderson-Fisk pre-test and the t-test score were:

Experimental_Group X_1	Control Group X_2	$\Delta \bar{X}$	t	A
10.950	14.558	3.608	3.105	$< 1\%$

It is to be expected that a group of science oriented students would have a better science background than students not so oriented. The starting scores for both groups on the Anderson-Fish Chemistry test show that the students of the Control Group are substantially better in the initial state of chemical knowledge.

The post-test results for both groups were:

	Experimental Group	Control Group	Standardization Group (Anderson-Fisk Manual)
Mean	18.3	24.3	26.0
Standard Deviation	3.4	7.3	8.6

The standardization of the Anderson-Fisk test, from which the above data is taken, was carried out in communities ranging from 10,000 to 100,000 population. The communities from which our Experimental and Control Group students were taken are all small (under 5,000 population). However, the data above would indicate that the rural students of the Control Group involved in this field test performed substantially the same on this test as the urban students of the standardization study.

The considerably smaller standard deviation found for the Experimental Group students, less than half that for the Control students, would show that the group tends to cluster around the mean. However, it may also reflect the small size (N = 20) of the Experimental Group.

The final achievement level of the Control Group students is higher ($\Delta X = 6.0$) than for the Experimental Group students. At least in part this is probably due to the initially higher starting level for the Control Group. Looking at the "gains" (post-score minus pre-score) and the percentage gains for both groups:

	Experimental Group	Control Group
Mean Gain	7.35	9.74
% Gain	67.1%	66.8%

Although the Control Group had a higher average gain, the percentage gain on the standardized chemistry test is almost identical for both groups. Considering the lower beginning level, lower ability level, and the fact that the Experimental Group students were not taking a traditional course, the above gain appears to be quite striking.

As a matter of fact, the Anderson-Fisk test was a very unfair one for the Experimental Group since these students were never given contact with the entire body of material measured by this standard instrument. In view of the foregoing, their record on this standard test indicates the value of the special course.

2. SPECIAL CHEMISTRY TEST:

The Special Chemistry Test was devised to measure the attainment of desired goals of the Special course. Test items in general covered the ability to make practical and realistic application of chemical concepts. The test results obtained on a pre-test given to both the Experimental and Control Group students are presented below:

Experimental Group X_1	Experimental Group Standard Deviation	Control Group X_2	Control Group Standard Deviation	$\Delta \bar{X}$	t	A
17.150	4.32	18.673	4.61	1.523	1.297	$>$10%

These data indicate that both groups had approximately equal ability in the beginning although the Control Group students were slightly higher.

The end-of-course means obtained on this test compare as follows:

	Experimental Group	Control Group
Mean	26.000	23.808
Standard Deviation	5.42	5.61

From these data it may be seen that the Experimental Group students had a post-test score average slightly higher than the Control Group. A comparison of the net gains and the percentage gains made on this test gave:

	Experimental Group	Control Group
Mean Gain	8.85	5.14
Percent Gain	51.6%	27.5%

The average gain made by the Experimental Group students is considerably higher than for the Control Group. This result was not anticipated since this Special Test should be quite legitimate for students of the "traditional", CBA, or CHEMSTUDY courses, and the Control Group students should have made substantially higher gains due to their exposure in depth to their course material. The percent gain made by the Experimental Group students was almost twice that for the other group.

CONCLUSIONS AND RECOMMENDATIONS

The purposes and objectives of this research have been met in the following manner:

1. A Special Chemistry Course was written at a level of understanding acceptable to non-science major and non-college-bound secondary school students.

2. The Special Course included a planned teaching approach making use of the inquiry method, audiovisual materials, re-teaching, and the use of the student's five senses in laboratory experiences.

3. The Special Course was field tested on a pilot basis, with results that indicate that the course can give the student a reasonable degree of proficiency in chemistry as compared with students taking the traditional course.

4. The students enrolled in the Special Chemistry Course, being primarily non-science majors and non-college-bound, were found to have less ability in reading, verbal reasoning, numerical ability, and abstract reasoning than the type of student taking the traditional chemistry course. This was an anticipated result.

5. Results of correlations indicate that it may be possible to achieve a reasonable degree of prediction for success in a chemistry course by means of pre-tests including reading, verbal reasoning, numerical ability, abstract reasoning, and initial level of knowledge in chemistry. This aspect will be pursued further on the basis of a more extended field test.

6. At one of the two schools giving the Experimental Course, pupil interest was rated quite high by the teacher on the basis of extra time voluntarily given by the student to finish laboratory work. There also was a desire on the part of some of the students to transfer from the traditional course into this Special Course.

7. Both schools involved in giving the Special Course during the academic year 1967-68 have indicated a desire to repeat the course during the coming year. In addition, some three to four other schools may accept the course during the coming year as part of an extended field test. This shows a general acceptance of its objectives and methods by interested teachers and administrators of this area.

8. The student populations involved in this field test were multi-ethnic, consisting chiefly of Anglo-Saxon or Spanish derivation students. Thus the results of this study should have some application to other areas with multi-ethnic student populations, and to students with less than average abilities as discussed in the body of this report.

9. The rather poor showing of Control Group students on the Special Test of this research study might indicate blind spots in basic understanding of this discipline, even for students who perform close to the national average on a standardized test. It is planned at some future time to make an item-by-item analysis of results on both tests by both groups of students. This might yield further interesting results.

10. The pursuit of this research study in all its aspects by the Principal Investigator, with the help of competent specialized personnel in certain areas, has given the Principal Investigator a reasonable training in the rationale and methodology of educational research. The same person intends to pursue a more extended field test of this course and other research aspects thereof. Thus the training received in this study is a useful asset which should, in the course of time, lead to further research experiences and results.

11. One observation resulting from the Principal Investigator's visits to the various schools involved in the field test may be worthy of note. It was found that in the schools with very small classes, an informality prevails which makes it more difficult to get down to work at the beginning of a class period. This results in a shorter actual exposure time on the part of the student in such classes. Where larger classes are involved, the students appear to settle in faster and the stage is set more quickly for the learning process to begin. Obviously, the teacher himself is a factor in the above and can exercise some control over the situation.

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APPENDIX

A. Special Chemistry Course for non-science majors

  1. Semester I, Text
  2. Semester II, Text

B. Special Chemistry Course for non-science majors

  1. Semester I, Lab Manual
  2. Semester II, Lab Manual

C. Measuring Instruments

  1. *Nelson-Denny Reading Test, Form A
  2. *Differential Aptitude Tests, Form L
  3. *Anderson-Fisk Chemistry Test, Forms E and F
  4. Special Chemistry Test, used for Pre and Post-Tests
  5. Semester I Tests
     a. 6 weeks
     b. 12 weeks
     c. 18 weeks (Mid-Term)
  6. Semester II Tests
     a. 6 weeks
     b. 12 weeks

D. Pre-Test Scores Table

  1. Nelson Denny Reading Test
  2. Differential Aptitude Tests
     a. Verbal Reasoning
     b. Numerical Ability
     c. Abstract Reasoning

* Since these are standard tests, they are not included with this material.

    3. Anderson-Fisk Chemistry Test
    4. Special Chemistry Test
E. Post-Test Scores Table
    1. Anderson-Fisk Chemistry Test
    2. Special Chemistry Test
F. Pearson Product-Moment Correlation Coefficient Table
G. T-Test Scores Table

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TITLE

A SMALL PROJECT RESEARCH PROPOSAL IN
SECONDARY SCHOOL SCIENCE EDUCATION

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PAGINATION ETC. Due to the fact that several of the Appendixes have been distributed previously and numbered at that time, there has been no pagination of the Appendixes for this Final Report.

RETRIEVAL TERMS--Descriptors: *Science instruction, science courses, test construction, test interpretation, *Testing Techniques, *Textbook preparations, *Instructional innovation, *Science curriculum, curriculum development, science course improvement project.

IDENTIFIERS--New Mexico, Chemistry, Education Innovation

ABSTRACT--A Special Chemistry course was designed and written for the nonscience major or non collegebound secondary school student. The course, including both text and laboratory manual, was field tested in two small rural schools of southwestern New Mexico, students from four similar schools acting as controls. Student populations involved were of mixed ethnic groups.

Pretest results showed that the Experimental Group students started at significantly lower ability levels in reading, verbal reasoning, abstract reasoning, numerical ability, and chemical knowledge. Despite this starting position, they made substantial gains on the standardized Chemistry test, and almost doubled the gains made by the Control Group students on the Special Chemistry Test.

A possible predictive factor for success in chemistry may be indicated based on correlations obtained.

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Special Chemistry Course Text

O.E. PROJECT 7G-045

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TO THE STUDENT:

You are enrolled in a most unusual course. We know that you are not interested in science as a career, and that probably you are not interested in going on to college. We feel that you still have a right, and in fact a duty to yourself, to learn as much as you can about the world you live in. The more you know about it, the safer you will feel, and the more secure socially you will be really.

We are designing a course specially for your benefit, and giving in on an "experimental" basis. The course will give you some facts, some theories, and plenty of opportunity to use your hands (as well as your mind) and all your physical senses to get acquainted with some new facets of your environment.

We are purposely giving you a rather small textbook. It is small because we are not going to give you a lot of facts to memorize, nor a lot of obsolete theory to learn, nor a lot of complicated mathematics, nor any historical names or dates to remember. These things have their place, but there are plenty of other books that you can refer to, if you like. Perhaps you will enjoy this course so much that you will want to learn more--we hope so, but it isn't necessary.

Primarily, we are giving you LESS to learn because we want you to learn what we give you well, and we want you to try to think about it and apply it. That way you should retain more in later years when it might do you some practical good.

In fact, we expect to stay in touch with you, and re-contact you a year from now, and perhaps two years from now, and have you tell us what benefits you have already gotten from taking this course.

Your homework and your lab work are designed to make you think, rather than just go through the motions. Do your homework by yourself, or in groups with friends--it doesn't matter. But however you do it, take an active part yourself; don't let somebody else do all the work or you will be cheating yourself. The same with lab work, except that here it will be mostly on an individual basis so that you yourself can feel, see, touch, smell, taste, and get acquainted with the world of science.

From the start BE ORDERLY. Orderly lab notes, well written homework, neat lab set-ups, all reflect an orderly mind, which is one of the most important goals, TO YOU, in this course. The mere reflection of a high degree of order in your thinking and in your work, whatever it is, can get you better jobs and better pay later in life (and sooner than you think).

The text for this course will be in loose leaf form. Also, there will be a lab workbook. You may be given a supplemental textbook, but if so, you still are responsible only for the material in this experimental textbook. If you have trouble with a concept, use other books--any of them that are available. Reading the same idea, but in different words of another author, usually helps your understanding of a concept.

You even might change your mind, and decide to go further in science as a career. If you do, this course still will provide you with a good foundation on which to build.

Once in a while, where there is one available, you will be shown a film on certain concepts. It is part of your instructional pattern, and not merely for your entertainment. However, besides presenting a concept, it will show you that scientists are real people handling real (even if sometimes very complicated) equipment. The films should inspire you, as well as teach you, by showing you what other people like yourself can accomplish.

We hope you will enjoy the experiences in this course, and reap real and lasting benefits from it in the years to come.

INTRODUCTION:

WHY should I study chemistry? Well, that's a very fair question, and it deserves a proper answer. Let's first look and see whether or not chemistry plays much of a part in your life. Do you ever go to the movies? Drive a Car? Eat or drink? Play baseball? Wear a dress, a shirt, or a pair of shoes? Use the telephone? Watch television? Play cards? Wash the dishes?

The list could be a lot longer; almost endless, in fact. In every one of these activities chemistry plays a very vital part. And as the world seems to get smaller, and more populous, that part will become much larger and more important in the future. Literally, chemistry today does apply to both cabbages and kings, and everything in between, too.

So, whether you want to or not, you are today living in a world largely shaped by modern chemistry, and you might as well get used to the idea. Really, it's a big, wide, beautiful and bountiful world, too, if you work along with it, and a knowledge of chemistry and all other sciences will help you get along in it that much better, and will help you appreciate and understand it better, too. You know, history has shown that the more the individual man is at peace with himself and with his environment, the more he understands both of these factors. This is reasonable, of course.

Now, in view of technical achievements, it must strike you that man has in large measure mastered his environment, and he has. He hasn't done such a good job of overcoming himself yet, but probably this will come about also, some time in the future. This lack of humanity in understanding itself is very serious, and science has given us some additional problems to face in this direction, but it really can't help it. You see, science doesn't know right from wrong, or good from evil. It just furnishes man with answers about his environment, and then leaves it up to him (and that includes you and me) to try to apply all this to improve our daily living. Don't blame science for this, and don't think that you or anyone else can hold back the hand of technical progress --you can't. The world's history proves that at a certain stage of development certain elements of progress will emerge, and if one individual does not discover the particular item needed, another one will.

Partly, this is due to the fact that we live in a very orderly universe. When you look around you, it may not seem so, but the deeper you go in understanding your environment, the more you will see this. As I write these words, I can look out the window and see the moon and two planets gently orbiting in their time-honored, closely-controlled movements in our universe. They are governed by immutable law as they whirl soundless through space. Similar laws govern other particles,

particles so small that we may never be able to see them directly, but that still will have a tremendous impact on your life and mine. And it's because of these unseen "laws" operating on all the substances in the universe that this hidden order is universally present. Of course, this makes everything much simpler for the person who is trying to understand his environment.

Another real benefit which man derives from understanding his environment better is the mental security it brings. The savage runs and hides from the loud sound of thunder, but we don't have to do this because we know that it cannot harm us. This is due to our increased understanding. The increased understanding also enables us to either change our environment when necessary, or teaches us how to adapt ourselves to it. If your home is flooded by heavy rain storms, you could move out; but if your knowledge permits, you might rather build a wall or a canal to divert the water and make it go somewhere else.

The fact that you have more than one way of handling a problem makes you more at peace with your surroundings, gives you a greater sense of well-being, and a real increase in security.

We have not yet really defined the words "science" or "chemistry", but we are ready for this now. A "science" is defined as an orderly, demonstrable body of knowledge about a particular subject. We have different sciences, such as astronomy, biology, chemistry, physics, etc., each dealing with a different subject area. Since in this course we are interested only in the science of chemistry, we will define this science as that dealing with material substances, their properties and interactions, and the laws governing them. Even this of course covers a lot of ground.

Now, despite all this huge technical progress which we can blame on chemistry, the latter is really only a lusty child, so far as age is concerned. Outside of a little hocus-pocus that really doesn't deserve the name, chemistry is only about 150 years old. I used to own a college textbook in chemistry dated 1863. The pages were small, about 5 by 7 inches, and the book only had about 140 pages. But this little book contained the COMPLETE knowledge of chemistry as of that time. You will, in this course, learn more about this science and what it can tell you about your environment, MUCH MORE than the most eminent scientist of that day could have hoped to learn.

Well, despite the fact that chemistry is a young science, many good, sincere, honest thinkers and seekers-for-truth have devoted their time, energies, and lives to it. We have a debt of appreciation to these people. Despite the fact that we will not devote time to historical development in this course, the lives of the pioneers of chemistry are a fascinating picture, and nobody can stop you from going to your library and doing a little reading in this area. It is really quite interesting.

The science of chemistry has been divided into several branches. For example, general chemistry (which is what you are studying here) deals with the general background, the most fundamental laws, properties of substances, reactions, measurements, etc. Organic chemistry deals with the compounds of the element carbon, because there are so many of them and their behavior has so many points in common. Analytical chemistry can be divided into qualitative (which tells us what kinds of elements or substances are present) and quantitative (which answers the question "how much?"). Physical chemistry handles the area of chemistry bordering on physics, and includes many more of the more complex phenomena and laws that can be dealt with in general chemistry. Biochemistry is concerned with the chemistry of living organisms and their products. A relatively new branch, nuclear chemistry has come into being to extend our field of knowledge about the particles of matter smaller than the atoms and molecules which are usually involved in the average chemical reaction. Thousands of people are engaged in theoretical or practical aspects of these and other specific areas of interest in chemistry.

Now, we are assuming that you are in this course because you do NOT intend to go into any branch of science; but remember that in your daily tasks you are already coming into contact with dozens of items which came into being, or have been improved or modified by chemistry. In addition, you will in the course of time grow up to become voting citizens, and technical issues are becoming more and more important in your world so you should have an intelligent background of science in order to make better decisions. Besides this, you will be supporting through your taxes a tremendous amount of research aimed at many targets, from making an improved strain of corn to landing on some of our neighboring planets. You should have a voice in shaping the destiny of the world you share, and you will want that voice to be a well-informed one.

Regardless of what you do with yourself in later years, even a modest knowledge of chemistry will make you feel more at home in the world. The air around you, the water you drink, and the very stones at your feet will have interesting stories to tell you, and you will be better equipped to listen to them.

Another thing you have learned already is that most people have problems to face as they go through life. We can't avoid problems, but we can have something to say about how we meet them, and this in a large measure determines what we do about them, and what the outcome is. In this respect, we can borrow a lot from the scientist because in the course of his work he (or she) usually has to face and overcome a great variety of problems. Now, there has in recent years sprung up something called the "scientific method", which is supposed to be a universal way of approaching problems so as to yield a desirable answer. In actual fact, there is no such universal way of solving problems. It's not quite that simple, and probably if you took ten thousand scientists working on ten thousand problems, you would find ten thousand different approaches.

But scientists DO have some things in common. They try to cultivate an attitude of mind which is logical; to put aside personal feelings in favor of an impersonal, "objective" approach; to evaluate and define the problem itself before they fly off in too many directions; to explore mentally all around the problem looking for the best approach (just as you might look for the easiest way up a steep cliff before you start to climb); to cast around for different methods of solving the problem (since many methods might work, but some would be less time consuming or less costly than others); to be able to try different solutions to the problem and be able to abandon them if they don't look too promising. Above all, they learn to be honest with themselves in evaluating their progress towards a solution. The latter quality of thought cannot be over-estimated, and has application in every walk of life. We do not always receive right answers to our problems, even after we try to the best of our ability. Sometimes this is because it doesn't fit our preconceived notions. We therefore pass up the right answer, and are led to accept the wrong one, or to think we have failed on this particular problem.

Historically there have been quite a few instances where again and again people found answers which wouldn't quite fit, but accepted them because they expected a certain answer. Later people of greater discernment came along, and found that the discrepancy between what was found and what was expected actually pointed to a new and unknown factor which they were then led to uncover and explain. The high standard of mental honesty on the part of these individuals led them to investigate small unexpected differences instead of glossing them over. You too can frequently learn more about an experiment that does not come out "right" by trying to reason out what factors affected your results.

Now, nobody can teach you these desirable attitudes of mind which we mentioned above. They are mental qualities which you will have to want for yourself, and you will have to exercise and apply them so that they become established habits of thought for yourself. All anyone else can do for you is to attempt to provide an environment, including some problems for you to practise with in developing your mental skills. But we can assure you that these mental disciplines will help you to approach other problems in life more confidently and systematically, with a greater assurance of success.

You will have a lot to learn in this course, but we are going to try to make it as easy as possible for you in the following ways:

1. By using language which is as simple as possible.
2. By leaving out historical development of chemistry, names, dates, and places.
3. By leaving out obsolete theory.
4. By attempting to tie in the material of this course with your daily experience as much as possible.
5. By using very little mathematics.

FOOD FOR THOUGHT:

1. WHY will the world of the future have to pay more attention to chemistry and related sciences?

2. Do you think that technical advances will demand changes in social science?

3. If this were not an orderly universe, what kind of a task would face the people trying to understand it?

4. What do you think about job opportunities for the future in science and technical fields?

5. Do you think that scientists would do a better job of governing the world than politicians?

6. Do you think that a modest knowledge of science could help you in the following jobs? In what way?

   a) gas station operator
   b) feed lot operator
   c) shoe clerk in a shoe store
   d) bank clerk
   e) secretary
   f) school principal
   g) truck driver
   h) farmer

7. Write a paragraph as to why increased understanding of his surroundings should make man more mentally stable.

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. (Do NOT ask discussion type questions.)

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 2--THE SCIENTIFIC METHOD:

You have probably already heard that there is a "scientific method" which scientists use to get new answers to their problems. There really is NO such single method, or system, which is guaranteed to get results for every problem. In fact, human nature being what it is (and even scientists are human beings), there are as many different methods of approaching and solving problems as there are scientists or problem-solvers.

However, despite the above statements, there are some common points of behavior which scientists CAN USE to approach and solve problems, and which most of them at least try to apply. First of all, they do NOT sit down and cry. They try to realize that, because the world and the universe do show a high degree of order and have been a relatively friendly place in giving up their secrets in the past, there probably IS an answer to their particular problem. This then brings them to the next step which is to try to define the problem, or break it down, into its simplest possible terms.

Having defined the problem as neatly as possible, the next logical step is to try to find out if anybody else has ever solved a similar problem. To find this out, the scientist engages in "library research", by going through journals and publications dealing with that particular subject area. Even if the library research does not provide a complete answer to the problem, in many cases it will provide a starting point for thought, or action, or both.

If a possible line of action is not suggested by the work of others, then the investigator will have to do some independent thinking at this point; or, failing to come up with a possible logical plan of action, he may just try several quick, simple approaches experimentally, just to see whether they seem to lead in the right direction. Usually, after trying several approaches to the problem, at least one will seem to show a little promise, and he is "off and running" in this direction. Another possible plan at this point is to try to arrive at a mental "model" which would suggest a possible solution to the problem. Experiments could then be designed to test the validity of the mental model. If the results come out badly, the model either is discarded or modified. If the results come out in accordance with the model, or reasonably so, further steps are taken to refine the model until it seems to express a proper answer to the problem. But the model serves a useful purpose in giving the worker something concrete to look at, handle, and think about, rather than merely an abstract concept.

Before an auto manufacturer builds a new car, for instance, he builds one in toy size to see what it will look like. In some cases he builds working parts to small scale also before going ahead with the full size project.

In the same way, the scientist tends to build a "model" of an atom or of a molecule. In his case he will probably never get to see the real thing, becuase of its tiny size, but the model helps him think about how it may be put together; how it may react; and so forth.

Models have been very useful in promoting scientific thinking, but we have to remember always that they are just models. When models no longer fit the newest facts and observations, they have to be changed or discarded in favor of improved models. The model is made just to help explain a concept or idea. It does not rule the concept or idea. The final truth may be quite different in some ways, from the models which our present thought might project for us. Meantime, they can be useful tools for building our understanding of science.

Continuing our thinking about the "scientific method", after having some degree of success in actually solving the problem, the scientist usually does not want to stop there. He usually wants to find out HOW and WHY the answer came about. In some cases, if he thinks he has learned enough about the general area of information involved, he may try to come up with a "theory", which is an attempt to explain certain natural observations. If he thinks that his theory is right, he may try to go another step further in testing out still further beyond the range of his present knowledge. He would do this by designing experiments to test the theory, and then carrying them out to see what kind of results are obtained.

To make a brief summary of the foregoing, details of the approach to a problem will always vary with the person, but the general steps are:

1. Define the problem--attempt to know exactly what you want, or what you are looking for.

2. Make observations--gather and record data under controlled conditions so that you can draw proper conclusions from the results.

3. Propose a tentative theory--try to find a reasonable explanation. Try to devise other experimental ways to prove it, or to disprove it.

A beginning course in science will not make you a qualified scientist, nor will you be able to do research that would demand an application of the scientific approach. However, you can mentally "see" the above steps in even the smaller problems that we work on, and keep the above steps in mind as we do our lab work. Doing this will provide more meaning for us, and more identification with the way science works.

FOOD FOR THOUGHT:

1. Do you think the "scientific method" has any advantages in approaching a problem over a hit-or-miss non-science approach? Why?

2. Can the "scientific method" of problem solving be applied to other everyday problems, or is it good only for problems in science?

3. Should a person who can think a little more clearly and logically be worth more as an employee? Why?

4. Do you suppose that all scientific progress in the past has been made by the "scientific method"?

5. If the "scientific method" of problem solving is good, why do you suppose it isn't used by everybody?

6. Does the "scientific method" require mental discipline, or can emotion and intuition play a large part?

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 3--MEASUREMENT

Now we say that chemistry deals with matter, its properties, and the changes that it can undergo. Just how do we know what changes take place, and why, and when? To start understanding something about such changes, both before and after the change occurs, we need some "handle" on material substances so that we can say: "Well, I know that a change has taken place because it looks different now (or it smells different, or tastes different, or has some other different quality." These qualities, or "properties" of matter, are the different ways that we can tell what a substance looks like, or tastes like, or feels like, etc.

Now, we usually talk about two different kinds of "properties"--physical or chemical.

Similarly, we define two kinds of changes in matter based on the above. One is physical change, and the other is chemical change. If a change takes place, but no NEW substance is formed, then we call this a physical change. If a change takes place and a substance is new and different from the original substance formed, then we say that a chemical change has taken place. Now, how do we tell if a NEW substance has been formed? We tell this by the fact that the substance formed has a different set of properties (both physical and chemical) from the former material.

This leads us into the next concept. In a few cases the properties of a substance are so obvious that they are easy to see and interpret. However, in most cases the problem is more complicated than that, and in order to establish a real difference between two materials, we must have something that we can measure. Such measurements, then, involve both kinds of properties--physical and chemical.

You could make measurements for yourself according to any kind of system or systems which you might choose. However, in this case, they would be useful only to yourself, and nobody else could interpret them unless they learned your system also. In order for different people to be able to measure things in the same manner, and be able to talk about them and think about them in the same way, a common basis for measurement must be used. In science today, the METRIC system is in worldwide use. It is also called the CGS system because it involved the CENTIMETER, GRAM, and SECOND as the basis for measuring LENGTH, WEIGHT, and TIME. There are, unfortunately, also some other systems still in use for certain specialized applications. For instance, the druggist uses grains and ounces. The carpenter uses inches and feet. Packaged groceries are sold by the ounce or pound.

Actually, it's a good thing to know something about all of these different systems because you will use them at one time or other in your life. By the use of conversion tables it's not too hard to go from one system of measurement to another.

In fact, we will spend some time on this in the laboratory. However, the main system you will work with in this course will be the metric system. One of the chief reasons for using this system is that it is based on a decimal system. In other words, the units of measurement vary in groups of ten. We will see what this means.

LENGTH: We have mentioned that the basic unit of length in the metric system is the centimeter. The centimeter is about four-tenths of an inch long (to be exact, one inch equals 2.54 centimeters). In scientific measurements we use rulers which are marked out, therefore, in centimeters, instead of inches. In turn, each centimeter is marked into ten smaller divisions called a millimeter, and thus ten millimeters make up one centimeter. Going in the opposite direction, ten centimeters make up one decimeter, and ten decimeters finally make up one meter. Look at the meter stick in the laboratory and get familiar with it. The kilometer is 1,000 meters long.

VOLUME: Since volume is simply length times width times height, each measurement of which can be expressed in terms of the centimeter as above, then the basic unit of volume in science is defined as the cubic centimeter. This is the volume occupied by an object one centimeter long by one centimeter wide by one centimeter high. We now jump to another common unit of volume measurement--the LITER--which is equal to one thousand cubic centimeters.

Another term for the cubic centimeter, which is used interchangeably but is preferred in modern usage, is the milliliter. As the name implies, this is the thousandth part of a liter. The laboratory equipment which you will use for volume measurements is marked ML in terms of the latter unit.

WEIGHT: On earth the weight of a piece of material substance is really a measure of the degree of attraction between the earth and the piece of matter. There are many different ways of measuring weight. For instance, a spring balance could be used, or a balance with two equal arms, or a balance with a system of weights and levers. However, the system of weights used for scientific work is based on a small unit called the gram, this in turn going to smaller units divided into a thousand parts, each of which is called a milligram. In the opposite direction, we take one thousand grams and lump them into a larger weight called the kilogram (or kilo, for short). Weights have to be used together with some kind of a device to make the necessary comparison between the object of unknown weight and the weights themselves. For this purpose, we use a scale or balance. Most balances have two arms of equal length, and when the object is placed on one side and a group of weights which balance it are placed on the other, then the total of the group of weights equals the weight of the object.

Balances are made in different sizes and styles, depending upon the range of weight you wish to determine. A tank holding a thousand gallons of liquid in a factory is weighed on a different kind of scale, or balance, than you would use to weigh water in a small beaker. Also, the jeweler weighing out a diamond would not be able to use a butcher's scale. So, the weighing equipment which is used depends upon the approximate weight involved.

There is a useful general concept to be made here. A mechanic does not pick up a wrench whose jaws open only to an eighth inch to tighten a bolt which measures two inches across. In science the tools also have to be selected to do a particular job, otherwise you get misleading results, or none at all. To measure the size of a small object you need a ruler with small divisions. To measure a large volume of liquid, you need a meter or other device which will do the job in a reasonable amount of time. To weigh a small diamond, you would need a very delicate balance and an equally fine set of weights.

Always match the equipment, and the method used, to the problem if you want results that have meaning.

TIME: In science the second, minute, and hour are still the basic units of measuring time, so you won't have to learn anything new here. For small amounts of time you will have to use a stopwatch, which measures down to a fifth, or even a tenth, part of a second. Stopwatches are not easy to read, and if you use one, you will have to be very careful that you interpret the readings correctly.

TEMPERATURE: Energy changes are always associated with chemical changes. Since energy is usually added to, or given up from, a chemical change in the form of heat energy, we have to have some simple and easy way of measuring this energy change.

When you don't feel good, the doctor takes your temperature with a device called a thermometer. We use thermometers a lot in science, but they are based on a different "scale" from the one used by your doctor. In medicine, weather reporting, baking, and other everyday tasks we use thermometers which are graduated in the "FAHRENHEIT" system.

In this system, water freezes at 32°, boils at 212°, and there are 180 little spacings, or "degree marks", in between these two points.

Scientists are a little more systematic, and their temperature scale (called the "CENTIGRADE" system) reads 0° at the freezing point of water, and 100° at the boiling point of water. So it has a range of exactly 100 little spacings (or degree marks) in between these two. As you can see, it is actually a little simpler to use.

For reasons which you will see later, there is another temperature scale in scientific use. This one is called the "ABSOLUTE" system. It has the same spacing for its "degree" marks as in the Centigrade system, but it starts at a much lower point. The zero mark on the Absolute system is way down at -273.0° Centigrade. Thus, 0.0° Centigrade is the same temperature as +273.0° Absolute.

The Absolute temperature scale comes in very handy when dealing with gases since the volume changes of gases with respect to temperature follow along with the Absolute scale. We will see this a little later.

Heat energy is a quantity, and temperature is a quality which is used in measuring heat energy. This difference will be made clearer as we proceed in the course.

PRECISION AND SIGNIFICANT FIGURES: We need to learn something at this point about the two new concepts stated above before we can actually make any useful measurements for ourselves.

Precision is a term which describes how valid, or how trustworthy, a measurement (or group of measurements) really is.

The precision of a measurement is described mathematically in a very simple way by the number of "significant figures" expressed in the measurement. For example, if you measure a desk with a ruler marked only in centimeters, and the measurement comes out near the 37 mark, you would note and write down that the desk measured 37 centimeters. This notation would tell another interested person that you measured the desk only to the nearest centimeter. If, on the other hand, your ruler was marked in millimeters, and the desk measured 37.4 to the nearest millimeter mark, then reporting the measurement to that nearest decimal place as 37.4 cm. would tell everybody else that you actually measured the desk to the nearest millimeter.

If you weigh a piece of ore on a crude balance and report a weight of 114 grams, then this tells anyone looking at your results that you weighed that piece of ore to the nearest gram. But if you weighed the same material on a very good balance with a good set of weights, and arrived at a weight of 114.8942 grams, then this figure would tell another interested investigator that you weighed the material to the nearest tenth of a milligram. He would also assume that your balance and set of weights was delicate enough to justify your reporting the weight to such a precise figure.

Do not confuse significant figures with decimal places. The figures 1.37, 0.00137, 1,370,000, and 0.0000137 all have only three significant figures. The decimal point is needed, of course, to give the proper value, but it has nothing to tell you regarding the degree of confidence of each measurement.

On the other hand, the figures 3.6900, 36,900. and 0.0036900 all show five significant figures, indicating a greater degree of confidence in these measurements.

So you see that you have to exercise judgment in making measurements in all of the following ways:

1. Use equipment which fits the job.
2. Measure to the degree of precision needed to do the job.
3. Report your results in such a way (using the proper number of significant figures) so as to indicate to everyone else the precision, or degree of confidence, of the measured value.

There are many ordinary but useful measurements in science which combine more than one type of measurement. You are already familiar with some of these. For example, speed of an object is the distance it travels per time interval. You usually measure it, in a moving auto, as miles per hour.

Density of an object is its weight per unit volume. In the CGS system it is measured and shown as grams per milliliter.

Solubility of a chemical is frequently measured and expressed as the amount of the chemical which will dissolve, in terms of grams per 100 grams of solution.

In figuring the comparative cost of two cans of peaches on the grocery store shelf, you would need to reduce the data to one of price per unit weight. This is a frequently used measurement.

Percent Purity of a material would involve the weight of pure material per 100 grams of total material. For example, most chemicals in industry are not 100% pure, but are bought and sold on the basis of their "active ingredient" content. If you were buying ground soybean meal as a cattle feed, you should take into account the percentage of water, and other possible "diluents" or "contaminants", before you make a decision as to whether one brand is better than another.

Man's ability to measure spans a fantastic range of values. The smaller particles of matter, on the one hand, have been measured to be in the neighborhood of $\frac{1}{13,000,000,000,000,000}$

inches.

The diameter of our solar system, on the other hand is 7,300,000,000 miles. Both the very large and the very small measurement have been made, as you can see, to a confidence of two significant figures. But many other measurements can be made much more precisely, and require us to record them with seven or eight, or even more, significant figures to show their degree of confidence.

FOOD FOR THOUGHT:

1. Do you suppose that scientists can measure: a) the absolute weight of an atom; b) the mass of the earth; c) the space between molecules; d) the amount of electrical charge in lightning; and e) the speed of sound? Find out from other reference reading about these.

2. If some fellow student told you he could type at the speed of 61.4539 words per minute, what would you think of his report?

3. Do we have "conversion tables" that will tell us the relationship between ounces and grams, feet and centimeters, miles per hour and kilometers per second? Where would you look for this kind of information?

4. If somebody tells you his car is fourteen feet long, what degree of confidence would you have in his measurement?

5. If somebody hands you a tape measure, would this help you in trying to measure the speed of light?

6. If you are trying to determine the difference in density between a piece of brick and a piece of gold, each weighing about 5 grams, could you use a cheap balance weighing to the nearest tenth of a gram?

7. If you clock the speed of an auto, and find that it goes 21 feet in 30 seconds, should you report the speed as: a) 47.7 miles per hour; b) 48 mph; c) 47 mph; or d) 50 mph?

8. If the same product is sold in two sizes, which would you buy: a) a package containing 7 ounces for 43 cents; or b) a package containing 250 grams for 45 cents?

9. The element mercury is a liquid that has a density of 13.6 grams per ml. What weight of mercury, in grams, would be contained in a small box measuring 5 cm X 7 cm X 8 cm?

10. Referring to the proper Table of Density, gold is how many times denser than: a) silver; b) iron; c) copper?

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 4--MATTER--ELEMENTS, COMPOUNDS, AND MIXTURES, IONS AND RADICALS

The physical sciences including chemistry are concerned with matter and its interactions, so the first thing that we need to answer is the question, "What is matter?" Matter is all around us. We touch it, smell it, see it, taste it, and come into contact with it; so it is about time that we learn something about it.

Now, all of the thousands and thousands of different things which you may deal with in your life can, first of all, be put into one of three classifications. A piece of matter is either an element, a compound, or a mixture. Now, since matter can be defined as something that occupies space and has mass, then obviously these three kinds of matter all occupy space and have mass.

We had better examine this word mass. It is an inherent quality, or property, of matter. We usually measure it as weight which is really the attraction between the earth and a particular piece of matter. Weight, therefore, serves as a measure of the mass of an object on the earth, and the terms mean almost the same in ordinary experience.

Now, over many years it has been found that certain kinds of matter could not be broken down easily into anything simpler however hard we tried. If we took a lump of such material (a piece of iron for example), and cut it into smaller and smaller pieces, each piece would still look like, and behave like, all of the other pieces of the same material. If this process were continued, sooner or later we would arrive at one last piece very, very small indeed which would still look like and behave like iron. If we could go further, and subdivide this piece still further, then we would find that we would no longer have the same material--that suddenly we would have a speck of matter which would NOT look like nor behave like iron any more.

These relatively simple materials which show a distinctive set of "properties" are called elements. There are only about 100 of them, and yet everything on earth is made from these "elements".

Going back to our story about cutting up a small piece of matter, if we start out with an element, then the smallest piece of matter which we could have, and which would still represent that particular element, is called an "atom". The atoms of a particular element are all alike, and therefore look and behave alike. In other words, they have the same "properties".

Gold is an element, and a piece of gold in China is the same as a piece of gold in the United States or in England. This is reasonable, especially if all gold atoms are alike, because the larger pieces are made up of millions of gold atoms. Each gold atom would look alike. (If we could see them; actually they are too small to see.) They would have the same identifying qualities or "properties", such as color, taste, odor, weight, etc.; and act similarly towards other kinds of matter.

Iron is a more familiar atom. Iron atoms are all alike in their size, magnetic properties, shape, odor, taste, color, etc., and they are also alike in their behavior towards other different kinds of matter. For example, all iron atoms can rust in air, can react with a chemical called hydrochloric acid, and can combine with sulfur, etc.

So each element represents a different kind of matter, relatively simple, which cannot be broken down further without destroying its basic identifying qualities, and of which the smallest particle is the atom.

Now, atoms of different elements can combine with each other, in different ways, to give thousands of other materials. Since these materials are formed by combining two or more different kinds of atoms, they must be more complicated than the elements themselves. These materials are called "compounds", and the smallest part of a compound that we can take is the "molecule".

The atom has the same relation to an element as the molecule does to a compound. Thus, if we were to take a piece of a compound, and cut it smaller and smaller, the smallest piece we could have which would still have the identifying qualities of that particular compound would be the molecule.

To take an example, copper and sulfur are both elements. They can combine in a chemical reaction to give copper sulfide, which is a compound. Before the reaction, we had separate atoms of copper (which were all alike). After the reaction was over, we had molecules of copper sulfide. The molecules of copper sulfide would be all alike, but they would NOT be the same as the original atoms of either copper or sulfur. That is, they would have a different set of qualities, or properties. They would look different, taste different, have a different weight, and other different properties from the two elements that went to form this compound material.

There are many thousands of possible combinations which could be made from the elements that are known today, and many of the materials which we deal with in everyday living are not pure elements, but are compounds made from two or even more elements.

There is a third kind of matter which we need to learn about. Instead of combining with each other in a chemical reaction which gives us materials with a different composition and a different set of properties than we had before, we could just *mix* different things together. As you may already have guessed, if we do this, we have a material called a "mixture".

Mixtures can involve either elements, or compounds, or both together. There are several features about mixtures that are handy to know. 1) Since mixtures are formed by mixing, which is a mechanical process, they can also be *separated* by some kind of *mechanical process*. 2) While atoms of different elements *must* combine according to some definite numerical arrangement, thus giving definite compounds, mixtures can be put together in any desired ratio, and thus have *NO* definite substance. Therefore, in a mixture you do not form something with a new set of identifying properties. Instead, in a mixture the properties will represent all of the original ingredients, and the final properties will be somewhere between the properties of the original materials which you put into the mixture.

So while mixtures are not too important in chemistry because they do *not* involve any chemical reaction, they are still important parts of our daily world; and they comprise many of the materials with which we come into daily contact, and which we use.

These three types of matter--elements, compounds, and mixtures --make up all the *materials* in the whole world. When you go home from school today, try to see how many different kinds of materials you can identify as *elements*, *compounds*, or *mixtures*.

A little later we will see that atoms (the smallest part of an element) and molecules (the smallest part of a compound) can gain or lose something which results in their becoming a particle with an electrical charge. So that you don't get confused later by this, we will tell you right now that the charged atom is called an "ion", and the charged molecule is called a "radical". To make the relation between these things a little easier to understand, we will make a little chart:

ELEMENT--A simple kind of matter with a certain set of properties.
Elements react to form compounds.

ATOM--The smallest particle of an element

ION--An atom having an electrical charge

COMPOUND--A more complicated kind of matter, made up from two or more different elements. Compounds also have their own particular set of properties. Compounds can be broken apart to give elements.

MOLECULE--The smallest particle of a compound

RADICAL--A molecule having an electrical charge

Let us give an easy example that will show this. We can take atoms of sodium (which is a light metal with rather unusual properties), and atoms of chlorine (which was the poison gas used in World War I). These materials are both elements. Sodium and chlorine will combine together in a chemical "reaction" to give a white solid called sodium chloride. Therefore, sodium chloride is a compound made up from the two elements, sodium and chlorine. The qualities, or properties, of sodium chloride are very different from the properties of either sodium or chlorine which reacted to form the sodium chloride. As a matter of fact, sodium chloride is just common ordinary table salt which you put on your food.

The sodium chloride is a compound, each molecule of it having one sodium atom and one chlorine atom. When sodium chloride is put into water, the water will conduct electricity; so we know that we have electrically charged particles in the water. Actually, the water solution of sodium chloride is found to contain both sodium ions and chloride ions.

Since there are so many elements, and many more compounds can be formed from them, the scientist has to use some "shorthand" way of writing chemical reactions. We will learn a little later about the "symbols", "formulas", and "chemical equations" that allow a chemist to write quickly and easily what happens in chemical reactions.

FOOD FOR THOUGHT:

1. Do you imagine that other solar systems could have elements not found in ours?

2. The element Helium, a gas, was first discovered in the sun. With your present state of knowledge in this course, what do we receive from the sun that could have caused this discovery? Confirm your answer with some reference reading. Where did the name Helium originate?

3. If everything in the world is an element, a compound, or a mixture, which class would the following common items belong to: a) a grain of sand, b) a gold ring, c) a brass key, d) an iron pot, e) a twenty-five cent coin, f) a piece of stone, g) a piece of glass, h) a piece of native copper metal, i) a bar of floating soap, j) gasoline, and k) table salt.

4. If the density of sulfur is 2.07 grams per ml, and that of quartz sand is 2.61 grams per ml, what density would you get for a mixture of these two materials containing 50% of each?

5. If the density of sulfur is 2.07, and the density of iron is 7.86, can you compute the density of the compound, iron sulfide, formed by reacting the two materials chemically?

6. You are given a mixture of powdered sulfur and powdered iron. Based on differences in physical properties such as solubility, magnetism, density, etc. (you can look up further properties in other books and tables), work out at least three different ways of separating the iron from the sulfur. Try to apply your brief knowledge of the "scientific method" in working out this problem.

7. Given a mixture of salt and water (a solution), what method could be used to separate the two materials?

8. Discuss WHY the physical properties of a mixture are somewhere between the physical properties of the component.

9. Discuss WHY the physical properties of a compound may be quite different from the elements which formed the compound.

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 5--PHYSICAL PROPERTIES:

In order to think about matter scientifically, we have to classify it; and in order to classify it, we have to observe and measure certain qualities, or "properties". We have already talked about some "properties" of matter. There are two types of such properties we can use: 1) Physical Properties, and 2) Chemical Properties. In describing matter, we usually use both types.

When you go home from school, and go into the house to eat your supper, how do your parents know that it is you? They can tell because you are a certain height, a certain weight, have a definite color of eyes and hair, talk in certain ways, and so forth. These are your identifying qualities, or "properties". This is how other people can recognize you and know that you are really you, and not somebody else. Similarly, physical and chemical properties serve to identify different kinds of materials.

PHYSICAL PROPERTIES: Let us take silver for an example, especially since it is rather well-known in New Mexico. Silver has a shiny, metallic appearance. It has a silvery color. It has a certain rather high density (that is, it weighs quite a bit for a given volume). It is "malleable" (this means you can flatten it with a hammer into rather thin sheets). It has no particular taste nor odor. It is a conductor of electricity. It will melt in a very hot flame (at 960.5° C to be exact).

All of these observations tell us quite a bit about the element silver. However, they don't tell us anything about how silver behaves in reacting with other materials. The properties we have just described are called "physical properties". In general they are defined as properties which we can measure without making the substance undergo a change in identity.

For your convenience in thinking about them, here is a partial list of physical properties:

color
odor
taste
atomic weight
ductility
transparency
solubility
hardness
freezing point
refractive index
elasticity
heat of fusion
conductivity
malleability
surface tension
heat of vaporization
viscosity

Some of these terms will not be very familiar, and we will describe them a little further:

1) Density is a property expressed by weight per unit volume,

normally expressed as grams per ml. Thus, to find the density of a piece of metal, for example, we would weigh it in grams, find the volume it occupies in ml, and divide the weight by the volume.

2) Atomic weights are actually the relative weights of the different atoms. We can read these from the proper tables; or we can actually carry out an experiment to combine one element with others, and figure out the relative weight ratio in which they combine.

3) Ductility: The ability of a material which allows it to be drawn through a small opening. Gold and silver are ductile metals, and can be pulled through small openings to be formed into wire.

4) Transparency: The optical quality of clearness. If a material is transparent, we can see through it. It is usually a comparative term with no recognized and accepted standards.

5) Solubility is the weight of one material that can be "dissolved" by a certain weight or volume of another. It is usually given as "grams per 100 ml of water", at a certain temperature. The "solute" (the dissolved material) can be a solid, a liquid, or a gas. Solubility changes with the temperature; thus the temperature has to be mentioned.

6) Hardness is a familiar property. Two materials can be compared by means of a finger nail scratch, scraping with a knife blade or with a diamond, or other ways. Many rocks and minerals are classified on the basis of their hardness values. Diamond is the hardest substance known.

7) Freezing point, as the name implies, is the temperature (in degrees Centigrade) at which a material "freezes", or changes over from the liquid state of matter to the solid state of matter.

8) Boiling point is the temperature at which a substance "boils", in degree Centigrade. Since boiling point (and also freezing point) is affected by pressure, the pressure has to be specified.

9) Refractive Index: This term is a measure of the ability of a material to "bend" light. It can be used only for transparent (or almost transparent) materials. It is a very easy and conveniently measured property, and can be measured very precisely with the right equipment.

10) Elasticity: The property which permits a material to

bend or be distorted without breaking. Rubber is elastic.

11) Heat of Fusion: The amount of heat required to change one gram of a material from the solid to the liquid state of matter. Do not confuse the actual temperature of this change (known as freezing point) with the amount of heat the change requires.

12) Conductivity: This property is a measure of the ability of a material to carry, or transmit, electric current. Wood and glass are poor conductors. Metals are usually good conductors.

13) Malleability: This property concerns the ability of a material to be flattened without breaking. Gold, silver, and copper are all malleable metals.

14) Surface Tension: This is a property of liquids which can be measured directly by the force needed to pull a small object out of a liquid surface, or by the height to which a liquid will rise in a small tube. Water has a high surface tension compared with other liquids, and compared with water solutions. Soap and detergents greatly lower the surface tension of water.

15) Luster: The appearance of a surface, such as "metallic", "pearly", "grainy", etc.

16) Heat of Vaporization: The actual amount of heat, expressed in calories per gram of material, which is required to change the state of a material from liquid to gas (or vapor) state. Water has a very high heat of vaporization --540 cls per gram.

17) Viscosity: Liquids (and gases too) show a definite friction. A steel ball, for instance, will drop more slowly through oil than it will through water even though the density of oil is much less. This resistance to flow, therefore, is connected with frictional forces in a liquid, and not the density. Viscosity is a very useful physical property used in industry to control manufacturing procedures that involve "viscous" materials or even flowing gases.

The "weight" of oil that you put in your auto engine is really based on viscosity of the oil, and not on its weight nor density. An easy way to measure viscosity is to compare the flow of liquids through small openings.

Physical properties are important in describing elements, compounds, or mixtures. However, when we want to know something about how one material reacts with another, then we have to observe and list their chemical properties.

PHYSICAL PROPERTIES are very often used as the basis of non-destructive testing. For example, the bottled solution sold in your grocery store for cleaning windows is a liquid mixture of chemicals. In order to check his manufacturing process, at frequent intervals he takes bottles from the assembly "line" and tests them to see that they are made the same as his desired formula. The tests used here are usually based on physical properties such as density, color, refractive index, etc., because such tests do not affect the material itself and he can return the unused portions back to his manufacturing process, and thus save money.

EQUIPMENT used to test or observe physical properties can run from the very simple to the very complicated. You can see the color of a water solution with your eyes, or you can measure it by a piece of equipment costing several thousand dollars. The use of equipment in this case does the job better, faster, and with greater precision. It also takes all personal factors out of the measurement.

Similarly, you can tell whether a battery is putting out electric current by touching the wires from the battery to your tongue; but it takes a sensitive and expensive meter to measure the current and give you a value which you can write down and work with experimentally.

The simpler physical properties can be measured with modest equipment. Density values, for instance, can be taken with a homemade balance and set of weights; but in general you get more accurate and reliable results from the more expensive and complicated equipment. Usually, the degree of confidence which you need in your answer is what determines what kind of equipment you use.

FOOD FOR THOUGHT:

1. What physical properties could you use to tell the difference between a block of wood and a block of copper metal?

2. What physical properties could you use to tell the difference between a solution of sugar in water, and a solution of salt in water?

3. What physical properties could you use to tell the difference between a block of copper metal and a block of iron metal?

4. If you were operating a soft drink bottling plant (such as Coca Cola), what physical properties of your product could you use to see that you are bottling the product properly?

5. If you worked in a factory that made pressurized hair spray, and a lot of the cans blew up in storage, what physical property would have to be investigated?

6. Gasoline has a lower density than water, and will float on water. What effect would this have, if you were trying to put out a gasoline fire with a water hose?

7. Carbon dioxide gas is generated by certain kinds of fire extinguishers. What particular physical property of this gas makes it suitable for this purpose?

8. In general, is it true that the elements with the heavier atoms are denser?

9. In order to make a balloon rise you need to fill it with a gas with one special physical property. What is that property?

10. What kind of material would you need, as far as physical properties are concerned, to make an "automatic sprinkler" which would let water come out in case of fire?

11. What particular physical property of x-rays makes them useful to doctors?

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In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 6--CHEMICAL PROPERTIES

The fact that gasoline burns in the presence of air or oxygen is a chemical property. It tells us how gasoline will "react" with other materials. In order to find this out, we would have to actually burn some gasoline, and this would result in making products which are quite different from the original gasoline and air that we started with.

Therefore, chemical properties are evaluated by chemical "reactions", resulting in the formation of new and different materials. In this respect, the evaluation of chemical properties is "destructive". If you are in the business of making anti-knock compound for gasoline, for instance, the only way you could properly test your product would be to put some in an engine, and try it out. In the process, your product would be consumed along with the gasoline.

Any chemical reaction involving a material is also properly a "chemical property" of that material since it describes how that material reacts and interacts with some other material. The fact that sodium metal is so reactive that it will react with water is a chemical property of sodium. The fact that sulfur will combine with copper metal when they are heated together is a chemical property of sulfur (and of copper too).

We will study many particular chemical properties in other parts of this course. Right now, we just want to become acquainted with what a chemical property is.

Chemical properties are extremely necessary and useful to the chemist, of course.

Sometimes, in manufacturing, there is no other good way of finding out certain information except by studying chemical properties. Drain cleaners, for example, are chemical products which react in sinks and drains chemically to help keep them clean. The manufacturer of such products actually has to take a certain number of containers and have them react under conditions of actual usage in order to see whether he has made the product properly. There are many other similar examples we could take where products have to be evaluated in terms of chemical behavior.

Chemical properties answer such questions as: 1) Will a material combine with oxygen? 2) Will a material combine with hydrogen? 3) Will a material react with other chemicals called acids? 4) Will a material decompose with heat or electricity? 5) Will a material give positive or negatively charged particles (ions) in water solution? There are many other possible questions--thousands of them in fact. We cannot study them all, but will instead try to take typical ones for the more useful and common elements.

The list here could be almost endless, depending upon how much work we want to do to properly describe the possible reactions for each element and compound. Much of this course will be concerned with observing different chemical properties for different materials, and then reasoning about them; so we won't go into too much detail right now.

Actually, in this course we are more concerned with your learning HOW to get such answers, and what you can DO with them, than in learning a long list of properties which you could look up in science books. The ability to reason is more important to you than the ability to memorize because you can apply it to other situations and problems in later life. We will, therefore, try to concentrate more on the HOW, WHERE, and WHY because answers to these questions can make you a better citizen, get you a better job, and give you a greater interest in life.

FOOD FOR THOUGHT:

1. When a plumber comes to your house to mend a pipe and melts some lead for this purpose, is he making use of a chemical property?

2. Is the rusting of iron a chemical property?

3. Water can be decomposed into two elements--hydrogen and oxygen--by an electric current. Is this a chemical property of water?

4. Some fire extinguishers produce a gas called carbon dioxide. What chemical property of carbon dioxide makes it suitable for this purpose?

5. Why is gold or silver used for filling teeth instead of iron which is a much harder material?

6. Light travels at a speed of 30,000,000,000 cm per second. Is this a chemical property of light?

7. Is house paint used for its chemical or physical properties, or for both?

8. Hydrogen is the lightest of all elements. Is this a chemical property?

9. The metal zinc will replace the element hydrogen from its compounds. Is this a chemical property of zinc?

10. If you are a manufacturer in the business of making anti-rust materials for auto radiators, would you have to test your product by physical properties or chemical properties?

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 7--STATES OF MATTER

Matter can exist in three different "states". If we take the same kind of matter, but in all three states, we find that the matter will show different physical properties, but will be the same in every other way. Thus, the change from one state of matter to another involves a physical change.

We will see quite a few examples of this later. In the meantime, our everyday friend, water, will help us to understand the states of matter. The water which you drink every day is the same material that the boys and girls of the northern United States use to skate upon in the winter time. When they fall, it hurts; and it hurts because they fall on something solid, called ice.

Ice has other useful properties. We put it into our drinks in the summer time because it helps to keep us cool. People in very cold climates transport things on sleds which ride over snow and ice; so it can be used as a road. However, ice, whatever we want to use it for, is still only water in the solid state. If you will think about it a little bit, you will decide that all solids have a definite shape and volume; and this is the usual definition of a solid.

In contrast to this, liquids are materials which have a definite volume, but NOT a definite shape. If you take a certain volume of milk, and pour it from one container to another, in every case it will assume the shape of the container. You do not, however, change its volume by doing this. This would be true of all liquids.

Gases (and vapors, which mean the same thing) are literally "free as birds". Materials existing in this state of matter have neither definite shape nor definite volume. Gases or vapors assume both the shape and the volume of their container. A little ammonia gas, for instance, injected in one corner of a large room, will make its presence known very soon in every part of the room.

In going from one state of matter to another, the main factor is the average distance between the molecules of the material. In the case of solids, the distance between molecules is rather small, and the molecular motion is thus reasonably restricted. In liquids, distances between molecules are larger than in solids. There is some increased freedom, but still not too much. In gases, the individual molecules are much farther apart than in either liquids or solids. In fact, they are so far apart that on the average they show relatively little mutual attraction, and can, therefore, expand indefinitely to fill their container.

going from one state of matter to another always involves a change of energy. Heat energy must be provided to melt ice (change ice to liquid water). Heat energy must be provided to convert liquid water to water vapor (a gas---steam). Going in the other direction liberates energy in the form of heat. This is also true for any material undergoing any change of state. However, remember that we are merely changing the physical properties of materials, when we accomplish a change of state.

The chemical properties of the compound water are the same, whether the water is in the solid (ice), liquid, or gas (vapor, steam) form. In any of its three "states", water will still react with sodium metal; and can still be decomposed by an electric current, for example. Naturally, chemical reaction rates, or "speeds", will be somewhat affected by the physical state of the water, but the over-all reactions (chemical properties) will be the same, regardless of the physical state.

Changes of state are very important to us in many ways, refrigeration being one of the most common uses. The entire useful principle of distillation, which enables us to separate many different solutions and purify many materials, is also based on a change of state.

Similarly, purification and separation of some materials can be carried out by differences in melting point, or in solubility, differences at low temperatures. Again, a change of state is involved.

An ice pack applied to an inflamed appendix or to an aching head can help these situations by absorbing heat as the ice melts, thus cooling the inflamed parts and bringing some relief. Here, the change of state from ice to water is used for its cooling effect since it absorbs heat from its surroundings.

In Texas, sulfur is "mined" from depths of several thousand feet by melting it in the earth and bringing it to the surface of the earth as a liquid. The change in state from solid to liquid sulfur makes this possible.

Notice that both elements and compounds (and even mixtures) can undergo changes in state. But NOT all materials can do this. In some cases they become decomposed, or otherwise destroyed, without undergoing a change of state. Wood is a good example of this kind of material. If we try to heat it, it burns or decomposes through chemical change, so we do not get a "wood vapor". Many metallic elements can undergo changes in state, but fairly high temperatures are needed to do this.

FOOD FOR THOUGHT:

1. In your experience, which of the following materials can undergo a change in state?

a) milk
b) butter
c) bacon fat
d) lead metal
e) mercury
f) engine oil
g) paint
h) ice cream
i) soda pop

2. Human beings experience a poisonous effect if they are around large quantities of mercury metal with an exposed surface. Why should this be the case?

3. On a cold day you can see water dripping from the exhaust pipe of your automobile. What change of state is involved here?

4. If you put a few drops of water on the palm of your hand and blow across it, it feels cold. What is the reason for this?

5. You are probably familiar with the local type of air cooler that uses water. Would this device work with milk instead of water? Why, or why not?

6. If you leave your house cold and unoccupied over the winter time, what can happen to it due to a change of state?

7. For every gram of ice that changes to water, 80 calories of heat energy are required for this change. If you put an ice cube weighing 25 grams into your drink of water, how many calories of heat are taken away from the water by the melting of the ice?

8. Why do people put anti-freeze into their auto radiators in the winter?

9. If you put a kettle of water on the stove and let it boil, eventually your kettle will become dry. What has become of the water?

10. For every gram of water changing to steam (water vapor) you have to put in 590 calories of heat energy. About how many grams of ice could be melted by 3 grams of steam changing to liquid water?

11. Sulfur dioxide has a Heat of Vaporization of about 80 calories per gram. If 1 gram of sulfur dioxide vapor condensed on your skin, would you get as bad a burn as if 1 gram of steam (water vapor) condensed on your skin, or a lot less burn, or a lot worse burn?

12. A steam engine, which was one of the earlier sources of mechanical power used by man, uses water in its operation. If water could not be changed from a solid to a liquid, would the steam engine still be able to operate?

13. Look up any necessary information in other books and decide whether or not you could run an "iodine engine".

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 8--CHANGES IN MATTER

Matter can be changed in several different ways. Some of these changes involve changes in physical properties only. An example of this would be the change of state of water in going from ice to liquid.

Some changes of matter involve changes in both physical and chemical properties. When copper metal and sulfur are heated together to form a new material, copper sulfide, both types of changes are involved.

Obviously, in a case like this we have accomplished a more fundamental change than just a physical change. We have literally "vanished" one (or more) kinds of matter, and have found in their place a different kind (or kinds) of matter. When this happens, we have actually accomplished a chemical change.

Everyday living at this time in the world's history is mainly based on such chemical changes (also called chemical reactions). The food you eat every day, the gasoline you burn in your auto, the film you watch at the drive-in movies, the flashlight you use after dark to change a tire all (and many more) depend upon chemical change for their activity in your behalf.

Fairly soon you will learn a little more about what matter is made of, especially about the smaller particles which are the "building blocks" for everything we see, feel, and call "matter". At that time, you will see that in ordinary chemical changes, or chemical reactions, only certain parts of the atoms are involved, but these ordinary chemical changes are literally what "make the world go round" for us. The thousands of useful changes which make our food for us, purify our water, drive our cars to work, give our airplanes power to climb into the sky, fertilize our fields to produce grain, regenerate the oxygen into the air for us to breathe, make the little sparks of light which are put together to form the picture on your television tube--all come under this classification of chemical changes.

How do we know when we have made a chemical change in some material? Well, that answer is rather easy. In a chemical change the original material (or materials) with its particular set of properties vanishes, and a new material with a different set of properties appears. The properties mentioned are both chemical and physical properties.

All right, let's try this out. Supposing we take some ice and melt it by applying heat, thus getting liquid water. We originally had a solid material, and we ended up with a liquid so we have accomplished a change of state there. Also, many of the physical properties of ice are different from water--density for example.

However, if we start to examine the chemical properties of ice and water, they are still identical. Both materials can be decomposed to give hydrogen and oxygen gas. Both materials will react with sodium metal to yield sodium hydroxide, etc. In every chemical change involving ice and solid water, they behave the same. Therefore, they must be the same material chemically, so this process of changing ice to water is NOT a chemical change. It was only a physical "change of state" of matter.

Instead, let us take a "mixture" of powdered iron and powdered sulfur. This time let us apply a flame to the mixture, and heat it strongly. We will notice that the mixture will actually burn, with a blue flame. When it has stopped burning and becomes cool, let us take a good look at the resulting product. The original sulfur was a yellow powder with no taste nor odor and a density (if we had measured it) of 2.07. The original iron filings looked like a powdered metal, and also had no taste nor odor, and were attracted by a magnet. The product after burning was a solid mass which no longer responded to a magnet, and most certainly did not look like either the sulfur or iron we started with. If we had put some of the original iron filings in contact with hydrochloric acid, they would have "fizzed" and given off an odorless gas. Sulfur with hydrochloric acid would not have given off any kind of activity, but the product of the sulfur and iron burned together, when treated with hydrochloric acid, gives off the odor of "rotten eggs".

From the above you can see that we have very definitely formed a material with a NEW set of both physical and chemical properties. We have made something quite different. Actually, this is an example of a chemical change.

There are many ways of proving whether or not such a change has taken place. The easiest is to try a few chemical properties. If the chemical properties of the materials formed by the reaction are different, you can be sure that you have brought about a chemical change, or chemical reaction.

Cutting a piece of paper into small pieces is not a chemical change. Filtering a suspension of sand and water will separate these two things, but their properties are the same as before, so this also is merely a physical change.

There is another good way of knowing whether we have made a chemical change in matter. Chemical changes take place between atoms and molecules, and thus take place only according to certain ratios *by weight* because different atoms and molecules have definite weights to start with; but physical changes can take place between materials without having any definite way of combining by weight ratios. For example, you can make a mixture of sugar in water in *any* desired ratio by weight. You could add one teaspoon per cup of water, or two, or six and a half, or any amount in between, and still have a mixture of sugar in water.

By contrast, when an atom of one element reacts chemically with another element, it must react with some *very definite number of atoms*. The simplest case is when just *one* atom of one element reacts with just *one* atom of another element.

When the compound sodium chloride is formed from sodium metal and chlorine gas, if you react *one* atom of sodium, it can react only with *one atom* of chlorine. To express this relationship, the "formula" of sodium chloride is written NaCl. If you took 1,327 atoms of sodium, it would require exactly 1,327 atoms of chlorine to react with this many. If you took 43 atoms of sodium, and 56 atoms of chlorine, then you would have 13 chlorine atoms left over because there would not be enough sodium to react with all of the chlorine.

Some atoms of elements require *more than one* other kind of atoms to react properly with them. (Some require two, or three, or even four.) Nonetheless chemical reaction always involves *small whole numbers of atoms* of different elements.

This is why you will see chemical formulas for different compounds written like: SO_2, H_2O, H_2SO_4, HNO_3, NH_3, $KClO_3$, and so on. The formulas themselves tell you *what kind of atoms* are present (that is, what elements are present) and *how many atoms* of each kind.

Thus, the formula for the compound H_2SO_4 tells us that every molecule of this material (which is called sulfuric acid) contains *two hydrogen atoms*, *one sulfur atom*, and *four oxygen atoms*. These seven atoms of these three different elements make up the compound sulfuric acid.

Since chemical changes *always* involve *changes in energy* of the system also, we could always include the energy change statement as part of the chemical equation. However, we *don't* usually bother to do this unless we are particularly interested in the amount of energy formed or used up by the reaction.

From the above statement, however, you can deduce that chemical reactions which produce heat energy (or any other kind of energy, for that matter) will end up at a lower potential energy level. It is very much like a large stone which can roll down hill. Before it started, it had a large potential energy. After it rolled all the way down and stopped, it had converted its potential energy into kinetic energy (energy of motion), and thus ended up at a condition of lower potential energy.

From the above analogy, you should be able to see that chemical reactions in which a lot of heat energy is formed, would tend to proceed more readily than those in which energy had to be supplied. Both kinds of reactions are possible, but in general it is true that reaction is more favorable when energy is released by it, just as the stone on the hill is more likely to roll down the hill by itself than it is up hill.

At any rate, it is desirable to know that energy changes are always associated with chemical reactions. The burning of gasoline provides the energy to drive your auto. The burning of natural gas can provide the heat energy to heat your home in cold weather. The burning of huge amounts of coal in power stations drives large electrical "dynamos" which make electricity to supply light for your house and business, make your refrigerators get cold to store your food safely, and even cook your food.

Chemical changes are frequently accompanied by the evolution of energy as both heat and light. The lighting of a match is an example of this. The special kind of reactions in which heat and light are both evolved is called a "combustion" reaction.

Sometimes, however, chemical reactions take place so slowly that they do not seem to give off or take up any energy at all. When iron combines with oxygen, it gives off heat. However, the slow rusting of iron would not seem to show this. In this case, the reaction of rusting is just so slow that the energy is also released very slowly. Sensitive measuring instruments would still prove, however, that the proper amount of heat associated with the reaction of iron and oxygen is given off.

NUCLEAR REACTIONS: A few natural elements can undergo a very unusual type of reaction in which certain invisible "rays" are also given off. We call these elements "radioactive". In recent years, man has been able to make similar materials in the laboratory, and has learned through this a great deal of useful and interesting information about matter's "building blocks".

The reactions which involve radioactive materials are NOT the ordinary type of chemical reaction. They are the result of very complex changes deep inside the atoms themselves. The resulting reactions of this kind also bring about changes in physical and chemical properties, just like ordinary chemical reactions. However, they also actually change the elements involved. Since it has been learned that the central inner part of the atom (called the nucleus) is concerned with such reactions, we call them nuclear reactions.

We will take up nuclear reactions in greater detail at a later point in this course. For right now, however, we need to recognize that this is another way in which matter can react. Just like ordinary chemical changes, nuclear reactions also always involve a change in energy. In this case, the energy changes are fantastically LARGE. "Atom bombs" are examples of this kind of reaction.

Another simpler and slower example of this kind of reaction is the natural decomposition of uranium to form common lead. The energy from this reaction can be actually seen as small flashes of light in a small instrument.

In your world of the future, nuclear reactions may become of much greater practical importance than today. At this time they either pose as a threat to world peace, or as a deterrent to large scale warfare. However, in the world of tomorrow these same nuclear reactions may help us to feed, clothe, and transport each other going about our daily business.

The field of nuclear science is very young, and much is still to be learned. Your tax dollars will go partly to open up this field of human knowledge.

REVIEW: We have seen that there are three kinds of ways in which matter can be changed:

1. PHYSICAL CHANGE: The materials involved will have different physical properties, but their chemical properties stay the same. Energy changes may or may not be associated with this.

2. CHEMICAL CHANGE: The materials involved before and after reaction have both different physical and chemical properties. Energy change is always involved.

3. NUCLEAR CHANGE: The materials involved before and after reaction not only have different physical and chemical properties, but actually form different elements. LARGE energy change is always involved.

This course will be concerned mainly with the first two kinds of changes.

"CHEMICAL CHANGES": There is one other very useful fact to know about chemical reactions. Like most other processes, they don't happen "all at once", but take a certain amount of time. Sometimes they are quite fast, but sometimes they are very slow. We therefore talk about the "rate of reaction" of a chemical change.

If you add a few drops of silver nitrate solution to a few drops of sodium chloride solution, almost instantly you get a white insoluble material formed which slowly settles to the bottom of your test tube. This is an example of a very fast reaction.

If you were to heat together some manganese dioxide and some hydrochloric acid, they would form a yellowish gas (the element chlorine). However, the reaction is not particularly enthusiastic, and will just about stop if you withdraw the flame. This is an example of a rather slow reaction.

Both fast and slow reactions have their uses. However, sometimes we want to speed up the "rate of reaction", or sometimes we may want to even slow it down. Do you think this can be done?

Yes, there are several ways of changing the rate of a reaction. For one thing, reaction rate is affected by temperature. In general, it is a good think to know that chemical reactions go faster at higher temperatures. The reason for this is known, and we shall see it later, in the chapter on Kinetic-Molecular Theory.

It naturally follows, then, that most chemical reactions would go slower at lower temperatures. This is why your auto battery may give you trouble in starting your car in cold weather. it just doesn't feel like doing all that work.

One of the most important things to us is the factor of keeping healthy with good, pure food. Bacteria and germs, which you already know are tiny plants or animals, also like to eat our food. If too many of them get there first, they make the food unsafe for us to eat; but the processes by which they digest and multiply are chemical processes, and are therefore affected by temperature. By keeping the food at low temperature until we are ready to eat it ourselves, we slow down the attack of our food by bacteria and germs so that very few of them breed in our food. This is the reason why food is kept in the refrigerator.

The pasteurization of milk is a similar process, but a little more complicated. In this process milk is first heated rapidly to destroy certain bacteria which are heat sensitive; then chilled rapidly to slow down the action of other bacteria and germs. It is, of course, kept cold until sold and used.

Another way of changing the "speed" of a reaction is by a "catalyst". We shall have to use some examples to explain how a catalyst works. Supposing that you needed five dollars to start a little business, but didn't have the money at all, and it would take you a long time to save that much. Then a friend (the catalyst) came along, and loaned you the five dollars. You started your business, and a few days later you gave him back his five dollars. In this example your friend acted as a catalyst. He enabled you to get started, but he got his money back from you very quickly, so he didn't lose in the deal.

A catalyst, then, is a material which changes the speed of a reaction, but is itself not used up by the reaction.

To take a chemical example: you can heat a material called potassium chlorate quite hot, and it will give off just a little bit of oxygen gas; BUT, if you add another chemical called manganese dioxide to the potassium chlorate and then heat them together, you get a lot of oxygen gas given off. When all the oxygen has been given off, you will find that the manganese dioxide is still there, unchanged. The manganese dioxide "catalyzed" this reaction, but was not used up itself.

You may perform this experiment in the laboratory, but if you do, be very CAREFUL. A dirty test tube, or too much heating, may cause an explosion that could harm you.

The above example, where a reaction rate was speeded up, was an example of positive catalysis. If a reaction is slowed down, we call it negative catalysis.

Negative catalysts can play a very useful part in your life. In fact, they already do. Whenever you put gas in your auto, the gasoline contains tetraethyl lead. This material was the result of long term research. It actually slows down the explosion, it prevents engine "knock", and reduces wear on your engine parts.

Edible oils provide further examples of both positive and negative catalysis. People are used to spreading fats on their sandwiches, rather than pouring oil over them. Since vegetable oils are cheap and readily available, as well as nourishing, they are converted into solid fats by a process called "hydrogenation", but to make the process go at a reasonable reaction speed, they use powdered nickel metal as a catalyst. Of course, the powdered nickel is taken out before the material is sold as margarine.

Since edible fats and oils turn rancid, and get a bad taste upon aging, chemicals can be added to slow down this reaction and thus give them a longer useful "life" and a better taste. These chemicals are negative catalysts for this particular reaction.

FOOD FOR THOUGHT:

1. What kind of matter change is associated with the following?

a) Riding a bicycle

b) Burning wood to cook your food?

c) Making electricity from radioactive materials

d) Boiling water to make steam

e) Growing a plant

f) Filing on a piece of iron

g) Mold growing on a piece of moist bread

h) Using anti-freeze to prevent damage to your auto engine

i) Baking a cake

j) Sawing a piece of wood

2. Do the following matter changes have an energy change associated with them? If so, is energy given off or taken in?

	Energy given off	taken in
a) Changing ice to water	_____	_____
b) Burning a piece of wood	_____	_____
c) Rusting of iron	_____	_____
d) Painting a red bicycle blue	_____	_____
e) The glowing of a firefly	_____	_____

3. Do you think that the slow rusting of a piece of iron would have the same amount of energy change associated with it as if you burned the iron quickly in a hot welding flame? Discuss this.

4. Some of the different kinds of energy in the world are:

ENERGY:	PROCESS:
a) Potential	_____ l) atom bomb
b) Kinetic	_____ m) auto battery

c) Chemical

d) Electrical

e) Nuclear

f) Heat energy

g) Magnetic

_____ n) a large water dam

_____ o) a car going 60 mph

_____ p) melting ice

_____ q) refrigerator door catch

_____ r) auto generator

In the blank spaces match up the kind of energy involved in the processes given in the second column.

5. Chemical changes become much slower at low temperatures. Discuss what this could mean to you in trying to start an auto at a temperature of minus 10° C.

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 9--CHEMICAL SYMBOLS, FORMULAE, AND EQUATIONS

In order to describe even the simplest chemical change in words, quite a bit of writing would be needed. For example, to tell what takes place when we heat together a mixture of copper metal and sulfur, we would have to say: "One atom of the element copper can unite with one atom of the element sulfur to give one molecule of the compound copper sulfide." Of course you can react more than one atom of each element at a time, but for each atom of copper you must have one atom of sulfur.

Now, in order to shorten the time and effort involved in describing chemical changes, chemists have devised a special "shorthand". For example, the entire statement above can be expressed by:

(1) $$\mathrm{Cu} + \mathrm{S} \dashrightarrow \mathrm{CuS}$$

and this shorthand statement, which we call a chemical equation, says exactly the same thing as the words above.

The first thing we need is an abbreviated name for each element. These are called "Symbols", and you will find a list of the chemical symbols for each element in the back of this book, as Table 1.

In order to make it easy for us to remember the symbols, in some cases the first letter of the element's name has been chosen. Examples of this are (always use capital letters for the symbol):

C - carbon
O - oxygen
N - nitrogen
H - hydrogen

S - sulfur
I - iodine
V - vanadium
P - phosphorus

Most of the remaining elements have two letter symbols, such as (capitalize only the first letter):

Cu - copper
Zn - zinc
Al - aluminum

Si - silicon
Cl - chlorine
Br - bromine

You will have to memorize the symbols for most of the common elements, but since they are so easily related to their full names, it will be easy.

Now, there is another reason for using the chemical symbols in writing what happens in a chemical change. Used as in the example above, it tells us that one atom of copper reacts with exactly one atom of sulfur to give just one molecule of copper

Looking at the combination of symbols (CuS) which describes the product of the chemical change, actually tells us that copper sulfide (which is the name of this product) CONTAINS one atom of each of copper and sulfur. Thus this system of shorthand tells us what kind of atoms, and how many of each kind, make up different kinds of molecules.

There is still another relationship expressed by the "chemical equation" written above. Just like other equations, we can apply mathematics to it. In this case, if we write underneath each element the relative atomic weight associated with it, then the equation also tells us the weight relationships involved in the reaction.

Taking the same chemical change as above, we can write the equation a little more completely as:

$$(2)\qquad \begin{array}{ccccc} Cu & + & S & \dashrightarrow & CuS \\ 63.54 & & 32.06 & & 95.60 \end{array}$$

The numbers underneath each element were obtained from Table 2 in the back of this text, and represent the relative weights of the atoms involved. The number underneath the formula for copper sulfide was obtained by adding together the relative weight of one copper atom and one sulfur atom, since according to the formula for writing copper sulfide, this is what it contains.

With the numbers written as above, we can now see the weight relation between the materials which enter a chemical change and the materials which are produced from it. Translated back into words, we can say that: "63.54 grams of the element copper can combine with exactly 32.06 grams of the element sulfur to give 95.60 grams of a product copper sulfide."

In order to reason properly from a chemical equation, it must be "balanced"; that is, the same number and type of atoms on one side of the equation also have to be used on the other side of the equation. This is just another way of saying that we cannot create nor destroy matter (Law of Conservation of Mass), since if we wrote two atoms of copper (for example) entering into a chemical reaction, and only one atom of copper appearing in the final product, we would be trying to destroy matter.

The balancing of chemical equations is beyond the scope of this course, but you must know that in order to reason properly about the atoms and molecules taking part in a chemical change and about the weight relationships involved, you must work with "balanced" equations.

Let us take another simple example. Magnesium metal will burn in air to give a white powdery product called magnesium oxide. (The familiar "Milk of Magnesia" is a suspension (mixture) of this magnesium oxide in water.) We can express this chemical change by the balanced chemical equation:

$$\begin{array}{lccc} (3) & 2\,\mathrm{Mg} & +\;\mathrm{O_2} & \dashrightarrow\; 2\,\mathrm{MgO} \\ & 48.62 & 32.00 & 80.62 \end{array}$$

Again, the numbers underneath the elements were taken from the table, and represent the relative weights of each kind of atom. The number underneath the formula for magnesium oxide was obtained by adding together the weight of two atoms of magnesium and two atoms of oxygen.

This equation is a little more complicated than the first one because of the fact that we took two atoms of oxygen (which is shown by writing O_2 for the oxygen which entered the reaction. This was necessary because we have found that the common gases (like oxygen, nitrogen, hydrogen) actually do not exist as single atoms, but as "diatomic molecules" (that is as gas molecules which contain two atoms of the element). Thus, since we had to take at least two atoms of oxygen, we also had to take the same number of magnesium atoms. Also, in writing the weights of the materials entering into the reaction and evolved from it we multiplied the atomic weights by two for each of these elements to take this complication into account.

Now in any calculations regarding the weights of materials entering into a chemical reaction or evolved from it, we are NOT limited to the numbers shown. The numbers merely indicate the WEIGHT RATIOS for the substances involved, but you could take more or less than the indicated amounts. Let us work out some examples:

> Equation (3) tells us that it would take 32.00 grams of oxygen gas to unite with 48.62 grams of magnesium. If we took only 24.31 grams of magnesium, then it would take only:
>
> $$\frac{24.31}{48.62} = \frac{X \text{ grams oxygen}}{32.00}$$
>
> Solving for X, we find that the reaction would require only 16.00 grams of oxygen. This is applying a simple arithmetic ratio to the problem.
>
> Let's work this in reverse. How much magnesium steel

would we have to burn (combine with oxygen) to give us 10.08 grams of magnesium oxide? Set up the following simple ratio and solve for Y:

$$\frac{48.62}{80.62} = \frac{Y \text{ grams of magnesium}}{10.08}$$

Working out the arithmetic, Y = 6.08 grams of magnesium metal.

These illustrations will serve to show HOW the scientist uses the weight relationships implied in a balanced equation.

From the weight relationships, chemists know how much of one kind of material to take to react with definite amounts of other materials and how much product to expect from a chemical reaction.

To review briefly:

Elements are represented by symbols.

Compounds are represented by formulae which show what kinds of atoms are present, and how many of each kind.

Chemical changes (reactions) are represented by chemical equations which tell us what elements or compounds enter the reaction, what elements or compounds are formed from the reaction, and tells us the weight relationships of the substances involved in the reaction.

If we are interested in the energy relationships in a chemical reaction, sometimes we write the reaction to show what changes take place in energy. For instance, the equation:

$$2\ H_2 + O_2 \dashrightarrow 2\ H_2O + 119{,}200$$

calories (heat energy)

tells us that when two molecular weight's worth of hydrogen (4.032 grams) reacts with one molecular weight's worth of oxygen (which is 32.00 grams), it will not only give 36.032 grams of water, but also give 119,200 calories of energy in the form of heat energy.

FOOD FOR THOUGHT:

1. In the following compounds tell how many atoms of each kind of element are present, per molecule of the compound:

	NAME	FORMULA	ATOMS	ATOMS	
a.	Silver Bromide	$AgBr$	__silver	__bromine	
b.	Potassium Chlorate	$KClO_3$	__potassium	__chlorine	__oxygen
c.	Carbon Dioxide	CO_2	__carbon	__oxygen	
d.	Carbon Monoxide	CO	__carbon	__oxygen	
e.	Sulfur Trioxide	SO_3	__sulfur	__oxygen	
f.	Hydrochloric Acid	HCl	__hydrogen	__chlorine	
g.	Sodium Hydroxide	$NaOH$	__sodium	__oxygen	__hydrogen
h.	Calcium Carbonate	$CaCO_3$	__calcium	__carbon	__oxygen
i.	Sodium Carbonate	$NaCO_3$	__sodium	__carbon	__oxygen
j.	Calcium Hydroxide	$Ca(OH)_2$	__calcium	__oxygen	__hydrogen
k.	Ammonium Hydroxide	NH_4OH	__nitrogen	__hydrogen	__oxygen
l.	Phospheric Acid	H_3PO_4	__hydrogen	__phosphorus	__oxygen

2. To the nearest whole number, what are the "molecular weights" of the following compounds:

a. Zinc Chloride $ZnCl_2$ _____

b. Hydrobromic Acid HBr_____

c. Aluminum Nitrate $Al(NO_3)_3$____

d. Copper Oxide CuO _____

e. Sulfur Dioxide SO_2 _____

f. Carbonic Acid H_2CO_3 _____

g. Silver Nitrate $AgNO_3$ _____

h. Iron Oxide FeO _____

i. Potassium Hydroxide KOH _____

j. Ammonium Chloride NH_4Cl _____

3. What does it mean in a chemical formula when a number is written slightly underneath and behind the symbol for the element?

Example: CO_2, NH_3

Discuss this.

4. For the chemical reaction: $NH_4OH + HCl \rightarrow H_2O + NH_4Cl$, write in words what takes place, naming the compounds involved, the materials formed, and the weight relations associated with the reaction.

5. From the balanced equation: $2\ NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2\ H_2O$, how much sulfuric acid would react if you started with 40 grams of sodium hydroxide?

6. If water is decomposed by an electric current into its elements hydrogen and oxygen, do we have to put energy IN, or is energy GIVEN OFF by this reaction?

7. Will a piece of iron be heavier or lighter when it has become rusty?

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 10--PARTICLES OF MATTER

You can touch, see, smell, hear, and taste material substance which makes up the world around you, but just what is the ultimate make-up of these substances? Just what gives them their peculiar or unique qualities or properties? What determines that some of these substances are so-called gases, some liquids, some solids? What makes some of them denser than others; some of them taste sweet; some of them able to lubricate an engine?

For several thousand years man has done quite a bit of thinking about his environment. In most cases that was all that he did. Therefore, he never got any closer to a possible answer because he never put his ideas to an experimental test, never properly measured anything; thus, never could draw any worthwhile conclusions which could be used as the basis of further ideas and tests. Only in the last few generations has man wanted to go beyond pure speculation and state his ideas in the form of models and theories which could be proven or disproven by experimental means.

The results have been very fruitful. Despite the fact that we cannot see the ultimate particles of matter, we have learned more about them in the last fifty years than we did in the preceding 50,000, and the knowledge has, in turn, given us ability to work with these particles.

Atomic theory can get very complex. However, it can be simplified for a general understanding. First of all, ALL material substances appear to be made up of the same basic "building blocks". The main difference between one kind of matter and another is the number and arrangements of these building blocks. It is like saying that every house in a city is made up of concrete blocks. Despite this unifying factor, you could still have a large variety of shape, size, and style just by using more or less blocks and arranging them differently.

There are three of these basic building blocks for matter: the proton, the electron, and the neutron. These can be put together in many different ways, but the next simplest step is to form an atom. The atoms therefore are put together using different numbers and different arrangements of the proton, electron, and neutron, but their general make-up is quite similar, too, from one kind of atom to another. Actually, theoretical models and experimental proof point to atoms of every kind looking like a midget solar system. The protons and neutrons form the small central "nucleus" of the system, and the electrons circulate around it very much like the planets circulate around the sun in our own solar system.

There are many other particles that have been discovered and named in the past few years, but they add little to our basic understanding of matter, and they are not required to explain most chemical reactions.

So, instead of something perfectly solid and substantial, like a block of concrete, we actually find that matter and material substances are really rather "insubstantial"; that they are really composed of tiny spinning particles performing in predetermined orbits around each other, at set distances and speeds.

This does not mean that because they are less substantial than they seem to us we can make material substances appear or disappear at will, like a magician. Far from that being the case, one of the first and most fundamental natural laws states that "matter can neither be created nor destroyed". (This is the Law of Conservation of Matter.) Now strictly speaking this law is not quite true. In the atomic age, we have had to add a new dimension to it, based on increased understanding. You see the Law of Conservation of Matter was true for all reactions which did not affect that central "nucleus" we talked about. In other words, it was (and still is) true for all chemical reactions which affect only the outer shells of electrons.

However, experimental proof in the atomic age has shown that the nucleus can undergo certain reactions, also so-called "nuclear reactions"; and these reactions can and do result in the formation of other atoms with different masses. Thus material substance as we know it CAN be created or destroyed, under very special conditions, but the other factor which enters the picture is one of ENERGY. If material substance, even a little bit of it, is actually destroyed, then energy (a lot of it) is released.

So, we really have an equivalence between matter AND energy, and if we take both into account and realize that both are somewhat interchangeable, then our conservation law really does apply to all situations.

Just stop for a moment and think of the underlying ORDER of the universe. Think of the fact that ALL material substances are made up of rather a few basic particles which are common to everything, and that the number of particles and style of grouping these particles together result in all the different kinds of atoms and elements with such a wide variety of properties!

Now, remembering that electrons, protons, and neutrons are grouped together to make atoms, let's take a very simple case as an example. If we take just ONE proton, and just ONE electron, and have the electron circulate in an orbit around the proton at its proper predetermined speed and distance, we have the model for the hydrogen atom. If we take another proton, and another electron, and the same speed and orbit for the electron again, what would we expect to have? Of course. another hydrogen atom, just like the first one. We could keep on doing this a million times, and end up with a million hydrogen atoms, each one exactly alike; each one exhibiting the properties of the hydrogen atom the same as all the others.

So, in view of this example, we are forced to another general conclusion: namely that the atoms of any one element are all alike. They have the same number of subatomic particles. They have them arranged in the same way. They all exhibit the same qualities, or properties. All gold atoms are alike. Similarly, then, all copper atoms are alike. All mercury atoms are like all other mercury atoms, and so on. In each case, each different kind of atom has a "unique" set of properties which apply only to that kind, and no other kinds of atoms.

In other words, gold atoms have a certain density (a certain weight per volume of space occupied), and no other atoms, no other element shows this same density. Copper atoms have a certain color, and no other element displays this exact color.

Let us approach this view of matter from another direction. If you were to take a piece of pure gold and cut it in half, and in half again, and again and again, you would finally, in theory, get down to one small piece of material which still had all of the properties uniquely associated with the element gold. You would have one atom of gold, and you would have a collection of protons and neutrons in the nucleus with an assortment of electrons spinning around it in orbits which alone would give the particular and unique properties associated with the element gold. If you could go still beyond this point, and cut up the atom of gold, you would still have the same parts, the same numbers of electrons, protons, and neutrons, but you would have destroyed the atom of gold, and not have the particular set of properties which we ascribe to the element gold.

Now we know that there are other substances in the world we live in besides the simple elements. We know this from the fact that the elements themselves can undergo changes to give other substances which have different properties. Let us take an example. Most of us are familiar with the yellow lumps or powdered material we call sulfur. This is an element. The element sulfur has certain "physical" and "chemical" properties which enable us to describe its behavior pretty uniquely. As far as some of its physical properties are concerned, the element sulfur is tasteless (that is, it has NO taste), odorless (that is, it has NO odor), yellow in color, not soluble in water. It is a solid at normal temperatures, and has a density of 2.07 gms/ml. (That means that its ratio of weight to volume equals 2.07 grams per ml.)

Now if you take some sulfur and burn it, it burns in air or oxygen with a blue flame to produce a colorless, choking gas. Eventually, all of the original sulfur will vanish. The choking gas is fairly soluble in water, and will turn a piece of blue litmus paper red, which tells us that an acid substance has been formed. The gas also has a metallic, acrid taste. It has a density, if we measure it, of 2.8 grams per ml.

Obviously, some kind of reaction has taken place. The original sulfur has been changed into another kind of substance with a completely different set of properties, both physical and chemical. This reaction, in which one (or more) kinds of substances vanish, and one (or more) other substances with different properties makes it appearance, is a typical chemical reaction.

In line with what we said before, this chemical reaction has involved only changes in the outer "shells" (or orbits) of electrons of the sulfur atoms and of the oxygen atoms which took part in the reaction. The inner part of both kinds of atoms involved--the "nucleus" which contained the protons and neutrons--did NOT undergo any change in this reaction.

By careful experiment we could prove that material substance was neither created nor destroyed in the reaction. To do this, we would have to weigh the amount of oxygen and the amount of sulfur that took part in the reaction, and collect and weigh the sulfur dioxide which was the gas produced by the reaction. If we did this properly, we would find that the weights of substances entering the reaction would exactly equal the weights of substances produced.

Now in this reaction two different kinds of atoms (one kind from the element sulfur and one kind from the element oxygen) were involved. The reaction produced only one product, with only one measurable set of properties. Thus obviously two kinds of atoms have combined with each other to produce a more complex material substance than before. Material substances which include more than one element we call compounds.

Now, remembering that any one particular kind of atom with a particular set of physical and chemical properties is an element, there is one more identifying property that we have not yet mentioned. This is the particular weight associated with the atoms of each element. Just as the color, taste, density, and other properties serve to identify a particular kind of atom, so each kind of atom has a unique weight. Since these weights are very small, we do not usually deal with their true, or absolute value. Instead, we measure and use their relative weights with respect to other atoms. Now in order to do this we have to pick one element as a so-called "standard". At present the weight of the carbon atom taken as 12.0000 serves as such a standard.

By reacting various elements together, we find that they react according to definite ratios by weight. For example, one carbon atom can react with one oxygen atom in the ratio, by weight, of 12.0000 to 16.0000. Thus the relative "atomic weight" of oxygen would be 16.0000. By combining the various elements to give compounds and measuring the relative weights of the elements reacting with each other, we can arrive at values for the relative atomic weights of all the elements. Such a table can be found at the end of this book (Table 2).

The table of atomic weights can be very useful in predicting what weights of various substances enter into a chemical reaction, and what weights of various substances are produced by the chemical reaction. Of course we have to lean on the Law of Conservation of Matter to know that matter cannot be created nor destroyed in a chemical reaction, and thus that the total weight of reactants must equal the total weight of products.

Armed with a knowledge of some simple chemical changes, or reactions, and the table of atomic weights, we can write the relative weights of substances entering the reaction (called the reactants) as compared with the relative weights of reaction products, and thus predict how much product "yield" we can get from a certain amount of reactant "input". We will do this a little later.

Based on the behavior of certain substances in solution, by their ability to carry an electrical current, we have been forced to conclude that such substances themselves are electrically "charged". If we hook up a flashlight battery and bulb, but dip the connecting wires through some pure water to complete the circuit, we find that the bulb would light up only dimly. Pure water itself is a poor conductor of electricity, and this proves it. If we add some sugar to the water, the situation is still the same, and the bulb would still remain dim. However, if we add a little table salt and stir the water to make sure that it dissolves, we will notice that the bulb burns brightly. Clearly the salt has added something to carry the electrical current. Substances that do this we call "ionic" substances.

In the case of ionic substances, when they are put into water solution, they either let go of or pick up one (or more) of the outer shell of electrons. Since to start with each atom is electrically neutral, when an atom loses an electron (which has a negative charge), the remaining part is left with a net positive charge. If the substance gains an electron, then it ends up a net negative charge. These charged parts of atoms are called ions.

Similarly, compounds or parts of compounds can gain or lose electrons when dissolved in water and also carry electrical currents. The charged particles in this case are called radicals.

The process which takes place when table salt is dissolved in water can be described as follows:

> Table salt is a compound of sodium and chlorine atoms in the ratio of one of each kind of atom. Dissolved in water:
>
> Sodium Atom -- Sodium Ion$^+$ + 1 Electron
>
> Chlorine Atom -- Chloride Ion$^-$ - 1 Electron

What actually seems to take place is that the chlorine atom "captures" an extra electron from the sodium atom. Since the electron carries a single negative charge, this leaves the sodium ion with a single net positive charge and the chloride ion with a single net negative charge.

The resulting electrical charges of these ions, being free to move around in the water solution, act as a conductor of electricity, and carry an electrical current, exactly as a piece of conducting wire would do.

To review briefly the various particles of matter:

Elements are composed of atoms.

Atoms are made up of:

1) A nucleus, like a central "sun", which usually includes both protons and neutrons

Protons:

a) Have a single net + charge

b) Are heavy (about 1800 times heavier than the electron)

Neutrons:

a) Have no electrical charge

b) Are heavy (same weight as the proton)

2) One or more electrons, which circle around the nucleus like planets around the sun

Electrons.

a) Have a single negative charge

b) Are very light (about 1800 times lighter than a proton or neutron)

Thus we see that most of the mass, or weight, of an atom is concentrated in its nucleus, in the weight of the protons and neutrons.

Ions: some kinds of atoms can "ionize" by losing or gaining electrons thus becoming negatively, or positively charged "ions".

Compounds are composed of one or more elements:

Some kinds of compounds can "ionize" in water solution to give charged particles. If the charged particles include more than one element, they are called "radicals".

When we realize that ALL of the substances in the entire world are made up of only about 100 different elements, we can see that chemistry has greatly simplified our understanding of matter. When we realize further that ALL of these elements are made up of only a few basic particles, or "building blocks", we can appreciate the high degree of order underlying the entire material universe.

In general then, the three basic "building blocks" of matter (the proton, neutron, and electron) put together in different numbers and arrangements, make up all of the elements in the universe we know. This is very much like a child building little houses of different sizes and shapes from a set of little wooden blocks. In turn, the elements combine in many interesting ways to produce more complicated particles (molecules).

All material substances we see, feel, smell, touch, and come into contact with every day are either elements, compounds, or mixtures of these two kinds of substances.

The chemist has learned to find out what matter IS in order to make it do what he wants--to create new substances with desirable properties; to make rare materials cheap and abundant; to make cheap and abundant material still cheaper and more useful to daily life. In this way he contributes to understanding man's environment and mastering it for the ultimate good and enrichment of mankind.

THE PERIODIC TABLE:

In their attempts to establish order out of the many elements found, over the years chemists have attempted to fit them into some kind of pattern which would help to explain and even predict their behavior. The Periodic Table is the successful result. Since elements are made up of atoms which in turn are made up of protons, neutrons, and electrons, and since the properties of atoms are a result of how these particles are arranged and how many of them there are in the atom, then logically the Periodic Table arranges the various elements in the number and arrangement of these protons, neutrons, and electrons.

The result has been very good in showing that the properties of the various elements depend upon their logical order in this Table, and in predicting properties for certain elements even before the elements were discovered.

There is a copy of the Periodic Table in your classroom or laboratory. Look at it carefully. It can tell you quite a bit about the behavior of elements from their relation in the Table to more common ones.

FOOD FOR THOUGHT:

1. If you were interested in research to overcome the force of gravity, do you think it would do any good to start with the study of atomic forces? Discuss this.

2. Are the three basic building blocks of matter (proton, neutron, and electron) the ONLY subatomic particles found? Try to find out and list the names of others.

3. Do the nucleus and the electrons in an atom completely occupy all the space of the atom: If not, what takes up the rest of the space? Do some reading and discuss this.

4. If the nucleus of an element contains three protons, how many electrons must circle around the atom of this element?

5. The chlorine atom has seven electrons in its outer shell. The chloride ion has eight electrons in its outer shell. Draw the chemical symbol for both of these.

chlorine atom _____ chloride ion _____

6. Which element is the lightest of all _____? Which element has the simplest atomic structure _______?

7. Sulfur has a relative atomic weight of 32.06. Discuss what this means.

8. An atom that has lost or gained electrons is called an _______________.

9. A charged group of atoms is called a ___________.

10. One element was discovered on the sun before it was known on the earth. What is the element, and how was it discovered?

11. In the blank space put down whether the item represented by the symbol is an atom, an ion, a molecule, or a radical:

a) Na ____________________

b) H^+ ____________________

c) NO_3^- ____________________

d) CO_3^{--} ____________________

e) Ca ____________________

f) NH_4^+ ____________________

g) Li ____________________

h) SO_2 ____________________

i) Li^+ ____________________

j) $CaCC_3$ ____________________

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 11--VALENCE

As you have now learned, atoms combine with atoms forming molecules. Sometimes the combining atoms are of the same type. For example, one atom of chlorine can combine with another atom of chlorine to make one molecule of chlorine gas (which would be written Cl_2). Sometimes the combining atoms are of different types. One atom of chlorine can combine with one atom of sodium to give a molecule of sodium chloride. It is good to know at this point that the forces which hold similar atoms together are different from the forces which hold together unlike kinds of atoms.

Atoms don't have to combine always in one-to-one ratio either, as you will have guessed by now. Sometimes one atom combines with two atoms of something else. Sometimes one atom combines with three other atoms, or even more. Sometimes it takes two of one kind of atom to combine with three (or even five) of another kind of atom.

Fortunately for the scientist, and one of the things which shows the high degree of order in the universe, atoms always combine in the ratio of simple whole numbers. This means: (1) chemical changes take place between whole numbers of atoms. Obviously, a half an atom of copper could NOT react with anything because anything less than a whole atom no longer represents an identifiable element. (2) One, two, or three atoms of one kind of substance react with one, two, or three atoms of other kinds of substances.

Thus, we would NOT expect to find, and do NOT find, that 19.3 atoms of copper react with 4.25 atoms of sulfur. What we DO find, in chemical changes, is simple ratios of combination like one atom of iron combining with one atom of oxygen or one atom of sulfur, or two atoms of hydrogen combining with one atom of oxygen, or one atom of sulfur combining with two atoms of hydrogen, etc.

Let's look at some chemical formulae: SO_2 is the formula for a gas called sulfur dioxide. The formula tells you that a molecule of sulfur dioxide contains one atom of sulfur and two atoms of oxygen. Simple enough, isn't it? The molecule of ammonia gas, NH_3 then obviously contains one atom of nitrogen combined with three atoms of hydrogen. A molecule of calcium carbonate (limestone or marble), $CaCO_3$ is a little more complicated. It contains one atom of calcium, one atom of carbon, and three atoms of oxygen. From now on, whenever you see a chemical formula, you will know what kinds of atoms are present, and how many of each.

Also, of course, since you are now familiar with the Table of

Atomic Weights, you can tell the relative proportion too, by weight, of each kind of atom in the formula.

In fact, the chemical formulae of various compounds show you that relatively small whole numbers of atoms reacted with each other to form them. For instance:

$CaCO_3$	calcium carbonate	NO	nitric oxide
H_2SO_4	sulfuric acid	NO_2	nitrogen dioxide
HCl	hydrochloric acid	KNO_3	potassium nitrate
FeO	iron oxide	$NaCl$	sodium chloride
Fe_2O_3	iron oxide	KBr	potassium bromide
H_2O	water		

Now, the chemical property that determines just HOW one atom combines with another, that is in what ratio atom for atom, is called "valence". Certain elements practically always have only one valence: for example, hydrogen has a valence of plus one, and oxygen usually has a valence of minus two.

When elements combine to form a compound, they combine in such a way that the total net valence of the resulting compound is always zero.

In sodium chloride, sodium has a valence of plus one, and chlorine of minus one. In water, hydrogen exhibits its usual valence of plus one, and oxygen of minus two.

Even the more complicated looking compounds are not too hard to figure out. Sulfuric acid, above, has two atoms of hydrogen, one atom of sulfur, and four atoms of oxygen. With a valence of plus one for hydrogen, and minus two for oxygen, then the single atom of sulfur is expressing a valence of plus six.

In the iron oxide FeO, iron is showing a valence of plus two. However, in the compound Fe_2O_3, it figures out to a valence of plus three. This is not a mistake. Some elements, like iron, CAN exist in more than one valence state. In the compound sulfur dioxide, with the formula SO_2, sulfur is expressing a valence state of plus four, even though we have just seen that in sulfuric acid its valence is plus six.

Fortunately, there are not too many elements which can exist in more than one valence state, and the number of resulting compounds are relatively few.

To sum up, valence means the "combining ratio" of an element. Like atomic weight, it is a relative concept, so we usually take valence of hydrogen as plus one, and the valence of oxygen as minus two. Since most compounds involve hydrogen, or oxygen, or both, we can work backwards to find the valence of other atoms in unfamiliar compounds.

In ammonia, NH_3, the valence of nitrogen must be minus three (because it balances the three single plus valence bonds of the hydrogen atoms present). In sulfuric acid, H_2SO_4, the valence of the one sulfur atom figures out to plus six. In sodium nitrate, $NaNO_3$, the valence of the single nitrogen atom is plus five. In iron oxide FeO, the valence of iron is plus two. In iron oxide Fe_2O_3, the valence of iron is plus three.

By the way, just how do we know that the compound sulfur dioxide has the formula SO_2? Or the compound ammonia has the formula NH_3, for example? The answer is not too difficult. The chemist analyzes some of the compound; that is, he breaks it down into its component elements and finds out how much of each element is present. He can, therefore, divide by the atomic weight of each, and arrive at a number which represents the number of atoms of each element in the compound. We will try this a little later.

FOOD FOR THOUGHT:

1. For the compound $ZnCl_2$ (zinc chloride), which statement is correct:

   a. One atom of zinc can combine with two atoms of chlorine.

   b. One-half atom of zinc can combine with one atom of chlorine.

2. Why is one statement correct for Question one, and not the other?

3. In the following compounds, what is the valence for the indicated ion:

a.__N in NH_4OH
b.__Pb in $PbCO_3$
c.__S in $ZnSO_4$
d.__P in H_3PO_4
e.__C in CCl_4
f.__Ag in AgBr
g.__Na in NaOH
h.__Ca in $Ca(OH)_2$
i.__K in KNO_3
j.__Cl in $KClO_3$
k.__Ba in BaO
l.__P in P_2O_5

4. Can you name all of the compounds in Question 3?

a. ______________________
b. ______________________
c. ______________________
d. ______________________
e. ______________________
f. ______________________
g. ______________________
h. ______________________
i. ______________________
j. ______________________
k. ______________________
l. ______________________

5. From other reference books, list five compounds of chlorine, and five compounds of nitrogen in which these elements display a different valence in each compound:

For chlorine:	For nitrogen:
1. ____________________	1. ____________________
2. ____________________	2. ____________________
3. ____________________	3. ____________________
4. ____________________	4. ____________________
5. ____________________	5. ____________________

6. What is the valence of any element in the uncombined state?
____

7. A compound of hydrogen and oxygen was analyzed and found to contain: 11.1% by weight hydrogen and 88.8% by weight oxygen. What is the correct formula for this compound?
____

8. A compound of iron and oxygen was analyzed and found to contain 30.0% oxygen by weight and 70.0% iron by weight. What is the correct formula for this compound? __________

9. The total valence of the individual atoms in a compound always adds up to what number? ____________________

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In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 12--SULFUR

The substance sulfur has been known since ancient times since it is the "brimstone" mentioned in the Bible. In early days it was mined on the Island of Sicily, but in recent years most of the sulfur comes from Texas. Wyoming is also becoming a producer since the petroleum in this state carries a sulfur compound, hydrogen sulfide, from which sulfur can be recovered.

The mining of sulfur in Texas presented an unusual problem because the sulfur is in the form of a solid and deep underground. The problem of recovering sulfur was solved by an interesting process which sends down very hot water and compressed air through different pipes. The hot water melts the sulfur underground, and the compressed air forces it up to the surface through another pipe.

Sulfur is an element. Thus, the simplest unit of sulfur that we can take is the atom, and each atom of sulfur is alike and has the same physical and chemical properties. It is a fairly active element, and can combine chemically with many other substances. So, besides being found as the pure element, sulfur is found also in the earth in combination with many other elements. For example, the metals lead, zinc, and iron are found abundantly as lead sulfide (also called galena), zinc sulfide, and iron sulfide (also called pyrite or fool's gold). In some cases, sulfur is recovered as a "by-product" when treating the ore to obtain these metals.

The fact that sulfur can react with other substances to form compounds, and that we can recover the substance called sulfur from a large number of compounds, helps to establish the elementary nature of sulfur itself.

PHYSICAL PROPERTIES: Ordinary sulfur as we see it is a bright yellow solid usually sold as a powder. It is brittle. It has no taste nor odor, and does not dissolve in water. It is a poor conductor of both heat or electricity. It has a specific gravity of 2.07. This means that 1 milliliter will weigh 2.07 grams. Sulfur melts at 112.8^{o} which is not very far above the boiling point of water. It also boils at a temperature of 444.6^{o}, being converted to sulfur vapor. It is soluble in a liquid called carbon disulfide (highly flammable).

Thus we see that sulfur can exist also in all three states of matter, just like water. Like water, it requires energy in the form of heat to make the change from one state of matter to the other.

There are other physical properties which would serve to describe sulfur, but the above are enough because there is no other element which would fit the above properties.

We can make "mixtures" which include sulfur. Actually, sulfur mixtures are used sometimes in medicine for treating skin ailments. The old springtime remedy of "sulfur and molasses" is another example of such a mixture, but not one of any proven value.

If you take some powdered sulfur and mix it with small pieces of iron metal (iron filings), you would have such a physical "mixture". To an Australian savage, the separation of this back into its original two components (iron and sulfur) would present a very difficult problem. However, to more enlightened minds which know that physical mixtures can be separated by physical methods, the problem only demands finding the proper method. Actually, there would be several ways of accomplishing this: 1. Just pull a small magnet through the mixture a few times, thus collecting and removing the iron particles; 2. Dissolve the sulfur with a solvent (carbon disulfide), filter out the iron filings, and evaporate the solvent to recover the sulfur; 3. You could separate the two substances by means of a difference in density, like a miner can separate gold from rock dust; or 4. By carefully heating the mixture you could melt the sulfur or vaporize it, leaving the iron particles behind.

The above shows just a few of the rather ingenious ways of solving one small problem. Other methods could be used, but they all show that a physical mixture CAN be separated by some kind of physical method.

ATOMIC STRUCTURE AND VALENCE: If you will refer to a Periodic Table of the Elements, you will find that Sulfur has an atomic number of 16 meaning that it has 16 protons in the nucleus of the atom. To balance the net positive charge from the protons, there are 16 electrons orbiting around the nucleus, the outermost "shell" of electrons containing six of them. Since this is one of the electron shells that would like to have eight electrons to fulfill its condition of greatest stability, then we see that the sulfur atom usually combines with other elements by taking two other electrons from them, and this gives the sulfur atom a net charge of negative two. Thus, the usual valence of sulfur is minus two.

With a valence of minus two, sulfur can combine with other atoms which have a valence of plus two, atom for atom (one each). For instance, it can combine with iron (in the plus two valence state) to form iron sulfide, FeS; or sulfur could combine with atoms of plus one valence, such as hydrogen, But in this case, it would take two such atoms to satisfy the minus two valence of sulfur atoms, so the formula would be H_2S. Sulfur atoms with a minus two valence could combine also with elements having a plus three valence, such as arsenic. In this case, the resulting compound would have the formula As_2S_3.

Do you see how valence determines the question of "how many atoms of one element combine with how many atoms of another element"? It is easy enough if you remember that every chemical compound is electrically neutral. Therefore, the number of plus valences in the compound have to add up to the number of minus valences.

As a review on valence, oxygen almost always has a valence of minus two, and hydrogen a valence of plus one. With this in mind, let us look at a few compounds, and figure out the valence of each atom involved:

H_2SC_4 Since each hydrogen atom has a valence of plus one, and there are two hydrogen atoms, their valence adds up to plus two.

Since there are four oxygen atoms, and each one has a valence of minus two, that adds up to a total negative valence of minus eight.

Now, since the compound as a whole is electrically neutral, the actual total positive and negative valence must be equal. Therefore, the sulfur atom in this compound has a valence of plus six.

H_2S Since hydrogen atoms have a usual valence of plus one, and there are two of them, the total positive valence is plus two.

Since the compound as a whole is electrically neutral, then the only other atom involved, the sulfur, must be exhibiting a valence of minus two in this compound.

Well, we have learned something new. Very obviously, the same element can have different valence numbers in different compounds. This is quite true, and unfortunately makes life a little more complicated for the student; but the rules for figuring out the valence of an element from the formulas of different compounds are quite simple as demonstrated above.

Variable valence is related to the fact that different numbers of electrons might be gained or lost by an atom, depending upon the situation. Thus, although the sulfur atom, as stated, usually prefers to gain two more electrons and thus becomes an ion with a minus two valence, it has other choices. It can, instead, LOSE electrons, up to six of them, in fact. (Remember that it has a total of six in its outer electron shell.) If it loses all six, it will have a valence of plus six, as in the example above for H_2SO_4 (sulfuric acid), But instead, it can lose fewer than this number. For instance, in burning sulfur in air, it forms the compound sulfur dioxide, SO_2. In this compound, thus, sulfur has lost four electrons to have a valence of plus four.

There are other elements that also show a variable valence. If you look at a large chart of the elements, usually called a "Periodic Table of the Elements", you will see the valence listed there for each element, and you will be able to see at a glance whether an element has more than one valence.

CHEMICAL PROPERTIES: Well, we got a little ahead of our story, and in the last few paragraphs have mentioned already some of the chemical properties of sulfur, but there are more.

As mentioned, sulfur burns in air or in oxygen to give a blue flame, and the compound sulfur dioxide (SO_2). This compound is a gas, and it dissolves fairly well in water to give a solution with an "acid" taste which also turns a piece of litmus paper RED. This is an indication that the water solution of sulfur dioxide is an acid.

Sulfur dioxide has been used for a long time to bleach and preserve dried fruits, such as raisins and apricots. It was also used for quite a while as a fluid in refrigerator systems (especially commercial ones), but this usage is being replaced by other products.

Sulfur dioxide can be made to combine with oxygen even further. Under special conditions, it can accept another oxygen atom and give another compound, sulfur trioxide. This compound also has a sharp, "acidic" taste and smell and its water solution turns a piece of litmus paper RED, indicating that an acid substance is formed. The product in this case is actually sulfuric acid which is present in the battery of your auto.

Sulfuric acid has a vast number of uses in industry, so many in fact, that the production of sulfuric acid is almost a measure of a country's "civilization".

Sulfuric acid reacts with other chemicals in many ways. First of all, it is a very strong acid and reacts with alkalis (also called bases in chemistry). A typical example is household lye. This kind of compound reacts with an acid in what is called a neutralization reaction. A neutralization reaction always gives two reaction products: 1. water, and 2. a salt. The salt which is formed depends upon what acid and what base is used.

Sulfuric acid will react with many metals directly to give the sulfate of the metal. For example, it will react with zinc metal to give zinc sulfate. The equation would be:

$$Zn + H_2SO_4 \dashrightarrow ZnSO_4 + H_2\uparrow$$

Besides zinc sulfate, the reaction forms hydrogen gas as shown.

Sulfuric acid will hurt your skin and damage your clothing so it should be handled with care. Like burns from other acids, the burn should first be flushed with large amounts of cold water, and then "neutralized" with some baking soda or washing soda.

Sulfuric acid is used to make fertilizer, to purify crude oil, in the production of other chemicals, in making iron and steel, paints, synthetic fibers, plastics, and many other items of modern living.

Sulfuric acid has another useful chemical property. It is a "dehydrater". That is, it takes water away from other things. This property is used a great deal in what is called "organic chemistry", where we can create new compounds by reacting things in the presence of sulfuric acid. This is one reason it can burn your skin very badly because it very quickly removes water from your flesh and changes its chemical nature.

We have talked already about the compound hydrogen sulfide, H_2S. It is found in nature near sulfur springs and where organic matter decays such as in a swamp. Eggs contain a small amount of sulfur, and you can smell hydrogen sulfide from a boiled egg. This compound is poisonous when breathed.

Sulfur is an element, as you already know. Although it is reasonably abundant in the earth's crust, there are many elements that are present in much greater abundance than sulfur. In fact, eight of the most common elements together make up over 98.5% of the world's surface, as follows:

Oxygen	46.43%	Sodium	2.85%
Silicon	27.77	Potassium	2.60
Aluminum	8.14	Magnesium	2.09
Iron	5.12	Hydrogen	0.13
Calcium	3.62	All other elements	1.25

As important as sulfur is, it therefore still makes up only a fraction of the 1.25% under the heading "All Other Elements".

Elements in general fall under the main kinds: "metals" or "non-metals". A first and simple way to tell the difference is just by the way the elements look. Already you are familiar with some of the common metals in everyday experience, and know that they have a certain, shiny, "metallic" appearance. This appearance is typical of the elementary metals, although in some cases the metal does not always look like this due to other reasons.

Iron in the form of a fine powder looks black, and definitely non-metallic. Sodium metal, due to its extreme chemical reactivity, looks like a metal when you first cut it, but in a few seconds changes its appearance due to reaction with the air. However, both of these materials are metallic elements. In a few cases, materials can look metallic even though they are non-metals. The element iodine is one of these. In the solid form it looks dark grey and metallic, yet iodine is actually a typical non-metal.

In most cases, however, our general statement is true, and the metals have a shiny "metallic" appearance.

Metals have some other common physical properties. They are usually fairly dense, and they usually are ductile. Copper and gold for example have the high densities of 8.92 and 19.3 grams per ml, and they can be flattened by a hammer. The non-metals, in general, have a lower density and are brittle.

We have seen already that sulfur has the density of 2.07 grams per ml. A piece of solid sulfur when hit by a hammer will not flatten, but shatter into small pieces, so the usual non-metal is brittle.

If we take a battery and put it "in series" with a small light bulb, the bulb will light up. If we now break the electrical circuit and place the two open wires on a piece of metal, the bulb will light up again. This is because the metal can act as a "conductor" for the electrical current. This behavior is typical again for metals in that they can conduct electricity. Therefore, they are called "conductors".

Again, our element sulfur will not do this. The non-metals, therefore, in the form of the element will not conduct electricity, and are known as non-conductors. As we will see later when they are in solution and in the form of "ions", then even non-metals can also carry electric currents. However, we are considering now just their behavior in the form of the elementary atoms, and thus classify non-metals as non-conductors of electricity.

FOOD FOR THOUGHT:

1. If the Frasch process (melting the sulfur underground) had not been invented, what would we have to do to get sulfur from the Texas deposits?

2. If sulfur bodies exist several thousand feet underground, how would a prospector ever find them?

3. How would you separate a mixture of: powdered sulfur, powdered iron metal, salt?

4. From the density given for sulfur, how much would a block of sulfur 25 cms x 13 cms x 52 cms weigh, in grams?

5. Would sulfur melt in ordinary boiling water?

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 13--AIR--WE ALL BREATHE IT

We live at the bottom of an ocean of air, and life as we know it on this planet depends upon this material. Human beings have for thousands of years been taking this substance for granted, but the time is rapidly approaching when this will no longer be the case. Mankind is slowly choking on its own products of civilization, and if it wants to survive, this factor will have to be considered and improved in the very near future. Factories, automobiles, wind storms, and atomic experimentation account for most of the debris in the air which can amount to a very staggering weight of impurities over a large city.

Air even has political implications. It is the only substance common to all nations with no set boundaries and no effective way of being "policed". Until recent years this was not very important, but the products of atomic experiments last for many years, are relatively harmful, and easily get carried from one part of the world to another, thus posing a mutual responsibility which the world must eventually recognize and accept. We are becoming "our brother's keeper", indeed.

Air is a mixture of several gases. Two of these predominate, the rest being present in small amounts, but still of considerabl importance to us. In addition, like all other gases or liquids, air can carry a considerable amount of material by suspension. If the suspended material is fairly coarse, like sand grains, considerable movement or turbulence of the air may be required to keep the material in suspension. If the suspended material is fairly fine, it can be carried for long periods of time or practically indefinitely even with little or no disturbance of the air.

The element nitrogen is a gas, and comprises about 78% of air by volume. The element oxygen which is also a gas, is the one which is necessary to support life, and comprises about 21% of air by volume. In the process of breathing, this mixture is inhaled into the lungs where a chemical reaction involving the oxygen takes place. When the air is breathed out, or exhaled, much of the original oxygen is gone, and another compound (carbon dioxide) can now be identified in the exhaled air.

Fortunately for animal life, most green plants show a reverse cycle to the above, taking in carbon dioxide and producing oxygen gas. By this means, the air maintains its normal ratio of oxygen. However, you can predict what would happen to this oxygen cycle if, in the future, the plants in large land areas have to be cut down to make room for people.

OXYGEN: Oxygen is a very active as well as abundant element.

This is why so much of it is found combined in nature. One of the most usual reactions involving oxygen is in fact called oxidation (but this term has a more general meaning also), or the reaction of some kind of material with oxygen. When this kind of reaction is accompanied by heat and light, we know it under the familiar name "combustion". When this kind of reaction is also accompanied by noise and physical shock, we call it an "explosion". Actually, the factor that determines which of these is involved in the speed, or rate at which the reaction takes place.

The rusting of iron, which is the combining of iron with oxygen, usually takes place so slowly that you cannot see the change while it happens. However, this is an oxidation reaction. When you build a campfire, you are oxidizing the paper, wood, and other combustible materials. In this case, the high reaction rate is faster; heat and light are evolved; and your oxidation reaction is called "combustion". When on the fourth of July you set off a firecracker (probably illegally), the materials in the firecracker burn, or oxidize, so that they create a "shock wave" which can damage anything very near it. Also the extreme turbulence created in the air makes a loud noise, and you have accomplished a small "explosion".

Since oxygen is necessary for all of these reactions, you might guess that they would proceed faster if the oxygen were more concentrated. You would be right, too. In the case of explosives, the oxygen is provided right in the explosive material itself, and this is part of the reason for an extremely rapid combustion rate.

Animal and vegetable materials decay when they are left in moist air. This is caused by a process of oxidation, helped by certain small organisms called bacteria. The process is fairly slow, but is responsible for the spoilage of foods. Oxygen and moisture are necessary components of the process, and since a chemical reaction is involved, anything which would slow down the rate of reaction would also slow down the rate of spoilage.

Since reaction rate is usually accelerated by higher temperatures and reduced by lower temperatures, temperature control gives us one way of controlling food decay. Thus, refrigerators hold food at low temperatures and prevent food spoilage for extended periods of time; and frozen foods may be kept at extremely low temperatures for much longer periods of time without spoilage.

Other ways suggest themselves to prevent food spoilage--reducing the moisture content by drying the food; reducing the oxygen content by canning the material in a vacuum; completely killing the bacteria by high temperature; or using chemical "preservatives", or other means which would all act in this direction.

The changes produced in the food industry by modern methods of preventing spoilage have in the space of a few years revolutionized the foods available on our tables. Today you can eat strawberries in the middle of winter; have salt water fish for your dinner even though you live hundreds of miles fom the ocean; and have an entire meal frozen and prepared ready to eat in a few minutes.

With the world facing tremendous population increases, new sources of food must be found. The sea will be our next large source of food for a world standing on the brink of mass starvation. Modern methods of farming still need to be applied in many areas of the world, and could increase food production, but the cost of machinery and the breaking of traditional habits of working take more time than the rising population can permit.

We had better say a few words about something called "spontaneous combustion". As the name implies, this is a combustion reaction that can start all by itself. It can be caused when combustible materials are directly or indirectly brought to a high enough temperature to ignite themselves. Damp hay, which is subject to bacterial action which is a slow oxidation and generates heat, may get hot enough to burn. Rags containing turpentine or linseed oil, kept in a warm confined space, may slowly oxidize, raise their temperature still further, and eventually catch fire by themselves.

The slower oxidation reactions are not to be despised for their economic damage. The rusting of iron bridges, railroad tracks, and other man-made structures costs the world billions of dollars every year in repainting or replacement.

Fires in private property, forests, or industrial locations are much more spectacular, and take a yearly toll of life and wealth. Keeping in mind that fire is an oxidation reaction helps you to know what steps to take to prevent fires or put them out. If you don't save trash or litter, don't keep paint rags around, don't store combustible materials in warm places, don't handle flammable solvents near open flames, you can avoid most of the factors which cause fires. If you find yourself confronted with one, the fire can be slowed down by closing doors or windows to prevent more air from reaching it; may be put out by using water (except for gasoline and oil fires) to cool it down below its ignition point; may be smothered (if it's small), such as by putting a lid over a pan of burning grease on the stove; or frozen and smothered both, by means of a "dry ice" extinguisher which contains carbon dioxide gas under pressure. One of the most common and effective means of putting out small fires is by throwing some baking soda on them. This material generates carbon dioxide in the heat of the fire, and since the carbon dioxide will not support the fire, it smothers it very quickly.

Clothing fires are among the most dangerous to human life because if the flames are breathed in, they sear the lungs. They are fairly common for young children playing with matches, and occur sometimes in the laboratory. The first, and most important rule in handling a clothing fire, is to force the victim to lie down instantly, to prevent breathing in any flames. Then the fire can be smothered with your own jacket, or soda, a fire blanket, or water. The essential item is SPEED here. The fire must be put out quickly. A dry ice extinguisher is hazardous to use on clothing fires since the blast of freezing carbon dioxide can injure eyes and skin by the extreme cold developed.

Gasoline, so useful in providing power for your car, can be a Frankenstein monster if mishandled. Because it is such a common item of everyday life, it is frequently treated very carelessly, sometimes with tragic results. It should NEVER be used for cleaning clothes, tools, engines, or other items. It should never be stored in glass or other breakable containers, or in open or leaking containers, or indoors. On a warm day gasoline poured on the ground outside will vaporize in a few seconds, and can even be ignited by just walking over concrete, such as a driveway.

Fires usually start small, and at that stage can be controlled and put out fairly easily. Prompt and correct treamtent without panic can save lives, homes, and jobs.

It makes common sense to realize that if oxygen can get to a burning substance more quickly or more easily, it will burn faster. For this reason, very small particles of any kind of combustible (oxidizable) material when surrounded by air will burn very rapidly--in some cases fast enough to explode. These are the chemical facts behind the so-called "dust explosions" in coal mines, grain elevators, and dusty factories which can be just as violent and large scale as any ordinary industrial explosive such as dynamite.

Speaking of industrial explosives, there are quite a variety of them in daily usage. In some cases, they are made less violent, and thus more controllable and more useful by "diluting" the active ingredients with inert "fillers". An example of this is dynamite, made by absorbing the unstable and unpredictable liquid explosive nitroglycerine on wood pulp or powdered minerals.

As mentioned, oxygen is a gas. There are several methods of making it in the laboratory, but since it has quite a few industrial uses, the main and cheapest commercial source is from the air itself. This is accomplished by first removing the dust, water vapor, and carbon dioxide it contains, and then cooling it to a temperature so low that it becomes a liquid mixture of oxygen and nitrogen. This liquid mixture is separated into its two major components by a difference in their physical properties--in this case, a difference in boiling points for the two gaseous elements. In this way, both oxygen and nitrogen are obtained in relatively pure form in large quantities. They are stored under high pressure in strong steel cylinders.

The familiar gas welding and cutting torches use oxygen, plus some kind of combustible gas. The use of pure oxygen, instead of air, provides a much hotter flame because it gives a faster reaction.

Oxygen can be evolved by heating certain oxygen containing compounds to a high temperature. For example, heating mercuric oxide, silver oxide, sodium nitrate or potassium nitrate, or potassium chlorate will in all cases produce oxygen. There are some hazards involved. For example, mercury fumes are quite poisonous, and potassium chlorate may explode if heated with any combustible material (even a small amount of dust). Since water contains oxygen (as well as hydrogen), a safe and easy way to prepare oxygen is to "decompose" water by means of an electric current. The wire from each side of the battery is led into a test tube or bottle, filled with water and inverted in a pan of water. Oxygen will collect in one test tube, and hydrogen gas in another. Could you collect the gases in this way if they were very soluble in water? How about the relative densities of hydrogen and oxygen compared with water?

One of the large and growing sources of air pollution is the auto; and an expanding population and expanding economy will make this a very real future problem.

By recent legislation, most autos will be required to have special "after-burners" which will ensure more complete combustion of the gasoline, and reduce air pollution. Industry faces a similar problem, but there are ways of removing small undesirable particles from the air. The Cottrell "precipitator" works on the principle that most small air-borne particles (dust, smoke, etc.) are electrically charged. The impure air is sucked or pushed between metal plates which carry opposite electrical charges, and the charged particle is attracted to whichever plate carries a charge opposite to itself, and settles there. The collected dust can be removed at intervals. The Cottrell precipitator has saved millions of dollars worth of valuable "dust" resulting from industrial operations, but the device is relatively expensive to install and operate.

Air may be purified for breathing by methods which depend upon the contaminating substances present. Dust filters can be used to remove relatively large particles from the air such as rock dust in mines. Chemical filters can be used to react chemically with poison gases; or else tanks of pure oxygen gas may be used for breathing purposes where the air cannot conveniently be purified, as in a burning building or a gas filled room.

The nitrogen in the air causes trouble when one breathes air under heavy pressure by dissolving in the bloodstream in larger amounts than normal. Divers experience the effects of this in the "bends". The usual precaution is to "decompress" very slowly; that is to return to normal pressure breathing conditions so slowly and gradually that the body has time to throw off the excess nitrogen. Artificial "air" made with other inert gases replacing the nitrogen can be used also to help this problem.

HUMIDITY: Air can hold a variable amount of moisture (water vapor), depending upon the temperature. Warm air can hold more moisture than cold air. When warm air containing moisture is cooled to a lower temperature, eventually a point is reached where the air can no longer hold all the moisture (this is called the dew point); and below this the excess moisture comes out of the air as fog or rain.

The amount of moisture actually contained by the air as compared with the amount of moisture it could contain at that temperature is expressed as a percentage figure and called "relative humidity".

We are all familiar with the fact that steam (which is water vapor) gives off heat when it "condenses" to liquid water. The reverse is also true. When liquid water is converted to water vapor, heat is taken up in the process. Human beings and other animals are "air conditioned" by this process. When it gets hot they perspire, and the liquid perspiration evaporates from the skin (gets converted to water vapor). In this process heat is taken up and the skin is cooled thereby.

In regions of low average humidity, air can be cooled successfully by "evaporative coolers", or "water coolers". They work on the same principle as above. Warm dry air is forced by means of a blower through a porous "pad" which is kept wet with circulated water. The air picks up water vapor, but is cooled by doing so. This process is used to cool homes and business places, especially in the southwestern part of the United States and other desert areas. The process will not work in regions of high relative humidity.

Air has a definite resistance, or "friction". Rockets re-entering the earth's atmosphere at a high rate of speed will become hot due to the friction of the air. If their material is capable of oxidation, it may burn, or get so hot that human life could not survive. By coating the outside surfaces with materials that are already oxidized and are poor "conductors" of heat, temperatures inside a space capsule can be kept close to normal.

LIQUID AIR: Liquid air, liquid oxygen, or liquid nitrogen are common articles of commerce, and frequently used for their physical properties to obtain very low temperatures. The physical properties of many everyday materials are very different at such low temperatures, and some interesting effects can be obtained. For example, a piece of meat cooled with liquid air and hit with a hammer shatters into many pieces. A piece of lead, struck with a hammer, gives a bell-like tone. Liquid oxygen is somewhat dengerous to handle since if brought near combustible material and ignited the very rapid combustion rate may result in an explosion. Liquid oxygen is used in some rockets.

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 14--THE GAS LAWS

It can be fun to sit back at the wheel of your convertible on a hot summer day and drive at high speed with the breeze in your face and not a care in the world, but such a trip can sometimes end in disaster through a blowout. The cause of this can be traced to two natural "laws" which govern the behavior of gases under conditions of changing temperature and pressure.

Some very common examples will help make the operation of these laws clear to us. If we sit on a small balloon, for instance, we would expect it to get smaller. It does, according to a very simple arrangement (Boyle's Law) that says that for a given amount of a gas, the volume it occupies varies inversely with the pressure upon it.

To vary inversely means that if Condition A gets bigger, then Condition B gets smaller. To vary directly means that if Condition A gets bigger, then Condition B gets bigger also.

To put Boyle's Law in the form of an equation:

$$\text{Pressure varies with } \frac{1}{\text{volume}}$$

The second gas law (Charles' Law) says that for a given amount of a gas, the volume it occupies varies directly with the absolute temperature.

Notice the term "absolute" temperature. This is just why the absolute scale was devised because the behavior of gases needed it.

To put this second law into an equation:

Volume varies with Absolute Temperature

We can combine the two laws and put in an equal sign and a constant (K) which is needed to reconcile the various units of measurement involved. In this combination we arrive at the equation:

$$\frac{P \cdot V}{T} = K$$

The terms P (Pressure), V (Volume), T (Absolute Temperature) can be measured experimentally in several different "systems". The value of the constant K will depend upon whether you express pressure in pounds per square inch, for example, or in millimeters of mercury on a barometer.

Using experimental numbers for the above, you could find out how one factor (the Pressure, for instance) changes with a change in temperature or volume of a gas. However, we are not going into the use of this equation mathematically. We are concerned here with some uses and interpretations of the gas laws.

1. For gases involved in a chemical reaction, even though a definite weight of gas may be evolved, the volume it may occupy can vary over a wide range depending upon the conditions of pressure and temperature. Therefore, it is customary to specify a certain set of conditions (called "Standard Conditions of Temperature and Pressure") (also called STP for short) under which the gas is generated, and to calculate its volume under these conditions.

IF we want to know what volume the gas would occupy under other conditions of temperature and pressure, we can calculate it from the gas laws equation. That's what it is for.

2. If you look at the above "combined equation", and remember that K is actually standing for a constant numerical value, then by applying a little algebra you can see that if the value of T gets smaller and smaller (meaning that you are going to lower and lower temperatures) the values of P (Pressure) and of V (Volume) also have to get smaller in proportion.

In fact, carried to an extreme case, if the value of T approaches ZERO DEGREES ABSOLUTE, then BOTH the Pressure and the Volume values will also have to APPROACH ZERO.

This is true, but only up to a certain point. Even at Absolute Zero Degrees, the molecules or atoms of the gas will still occupy a space (even though very little space) and will never get all the way down to zero volume. In actual practice, we have been able to achieve temperatures only a tiny fraction of a degree above Absolute Zero, but never all the way down.

3. Let us get back to our tire. Fast driving creates friction, and friction in turn creates heat. On a hot day this heat cannot be dissipated quickly enough to the surrounding air, and a tire may slowly get hotter and hotter. (The value of T increases.)

Look at your equation again. Since the Volume (V) of the tire has to remain essentially the same, as T increases, the Pressure (P) has to increase in direct proportion. Thus, the pressure in your tires will go higher and higher. If it gets to the point where the tire strength is less than the value of the pressure (P), then the tire blows out suddenly, and you may end in a ditch.

4. There is a very natural explanation for the behavior of gases as expressed in these two gas laws by the KINETIC MOLECULAR THEORY of matter. We shall take this up soon, and you will understand WHY this relationship between pressure, temperature, and volume exists.

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 15--KINETIC-MOLECULAR THEORY

Have you ever watched dust motes glinting and dancing in a beam of sunlight in a darkened room? The particles probably were much too small to be seen by the naked eye (without a magnifying lens). What we actually see in this case is the tiny flash of light reflected from the particle.

Years ago a botanist named Robert Brown saw this same effect in a water suspension of tiny pollen particles, and it started him thinking WHY this should occur. If you set up a totally enclosed system of this type, you would find that the particles NEVER settle out and appear to be in perpetual motion (which is against ordinary physical laws of motion). Just what could cause this?

At this point your teacher will lead a brief discussion on this topic. ____________________________

The complete evolution of kinetic-molecular theory took place over a long period of time, but today is substantially as follows:

Except at temperatures of Absolute Zero degrees, ALL atoms and molecules of all substances are perpetually IN MOTION. The speed of this motion is proportional to their temperature, on the average, but individual speeds will range at any one instant from almost zero to a certain maximum (which depends on the temperature). Naturally the atoms or molecules will "hit", or collide with, other atoms or molecules, but such collisions must be PERFECTLY ELASTIC. That is, there must not be ANY loss of energy from the collision, and there must not be ANY loss due to friction or any other such force.

WHY is this PERFECTLY ELASTIC COLLISION a very necessary part of this theory?

Now the speed and distance of this motion for individual particles also will vary, depending upon their physical STATE. The particles in a solid are in motion, but the motion is much more restricted than in a liquid; and the particles in a liquid are much more restricted in their movement than the particles in a gas.

A block of solid gold clamped against a block of solid lead for several years has shown the presence of gold atoms in the lead, and vice versa. This shows the rather slow and restricted atomic motion in solids.

However, if you open a bottle of concentrated ammonium hydroxide, almost instantly you can smell the ammonia several feet away. This shows the extremely rapid and unrestricted motion of molecules in a gas.

To go back for a moment to the "Brownian Movement", if you take some extremely SMALL particles (so small that they are fairly close to the actual size of atoms or molecules themselves), these particles will be constantly "hit" from all sides by atoms or molecules of the liquid or gas in which they are in suspension. With a small enough particle, these "hits" will actually push it around in a haphazard, unpredictable motion. Again, with a small enough particle, the "hits" will be enough to KEEP it in motion so the particle will never settle out or come to rest. This is the explanation of the "Brownian Movement" in terms of kinetic-molecular theory.

This rather simple explanation of atomic and molecular motion can, and does, explain quite a few natural phenomena, including the two GAS LAWS we have already learned about.

You know that air in a tire or a balloon exerts pressure. Since, according to kinetic-molecular theory, the air molecules are in constant and rapid motion, they strike the walls of their container as well as each other. The total force of these collisions against the walls of the container causes the effect called "pressure" which we can measure on a suitable gauge or other device.

BOYLE'S LAW: What would happen if you take a container of gas and then in some way (such as a sliding piston arrangement) make the gas occupy only HALF its former volume. Well, you would still have the same number of molecules, and at the same temperature you would still have the same speed and frequency of motion (on the average); but in the latter case the gas molecules would only have to go HALF the distance before they hit the walls of the container and rebounded.

Therefore, you would have TWICE as many collisions against the walls, and exactly TWICE THE PRESSURE.

Can you plainly see now that "pressure of a gas varies inversely with the volume" and is a natural consequence of kinetic-molecular theory? This is Boyle's Law.

CHARLES' LAW: We have already mentioned that temperature is directly connected with molecular activity on the so-called "Absolute" scale. At ZERO DEGREES ABSOLUTE ($-273^{o}C$) almost all molecular motion stops, but as the temperature goes up, the energy of motion goes up in direct proportion. This is the kinetic-molecular explanation of Charles' Law.

We can measure this increase in energy with absolute temperature as either an increase of pressure (at constant volume), or as an increase in volume (at constant pressure).

For example, if we take a certain volume of gas at 20° C (293° A), and heat it up to 40° C (313° A), we can realize that the increased energy of motion imparts more frequent collisions to the walls of the container. This would result in a measured increase in pressure if we don't let the volume change; or, if we allow the gas to take up more room at the higher temperature (keeping the pressure the same as before), we will find that the increase in volume is directly proportional to the increase in absolute temperature. (In this example the volume would increase by a ratio of 313/293.

DIFFUSION: Kinetic-molecular theory explains such effects as diffusion. Drop a crystal of potassium permanganate in and even without any stirring it will dissolve slowly. The open bottle of ammonium hydroxide is soon noticed. With the molecules of gases indulging in millions of collisions per second and moving at very high speeds in between collisions, diffusion effects are easily explained. Remember that even liquids and solids are subject to diffusion, but at slower rates.

CHANGE OF STATE: Can you also see why it SHOULD take energy to go from one state of matter to another? Molecules of liquid water are in motion, but are also subject to mutually attractive forces (forces of cohesion) which place a LIMIT on their movement with respect to each other. The addition of a certain amount of ENERGY to the system is needed in order to give each molecule of water an average energy in excess of this mutually attractive force, and thus permit the molecules to behave as free gas molecules, or water vapor.

MOLECULAR MOTION: Let us compare molecular motions roughly for the different physical states.

> GAS: In a gas the molecules are relatively FAR APART from each other and moving VERY FAST in relatively open space. The situation has been compared with basketball players on a gym floor.
>
> LIQUID: In a liquid the molecules are relatively close, moving moderately fast. This situation has been compared with the streams of people leaving a stadium in constant but orderly fashion.
>
> SOLID: In a solid the molecules are VERY CLOSE together, packed in orderly arrangement, and with only a small amount of motion. The motion consists

of vibrations of individual atoms (or molecules) or layers around FIXED LOCATIONS. This situation has been compared with the spectators at a game sitting in their seats but making small restricted motions.

You should now be able to understand that it would take a certain amount of energy to get these spectators out of their seats, put them in motion, and headed for the exits in a reasonably fast-moving stream. This example shows by analogy what happens when a solid is changed to a liquid.

VAPOR PRESSURE: The tendency for molecules of a liquid to "escape" into the gas or vapor phase can be measured by its "vapor pressure".

Vapor pressure is a physical property in a liquid related to the average kinetic energy of the liquid molecules. Therefore, you can see that vapor pressure will increase directly with temperature.

When the temperature of a liquid is raised to such a point that the vapor pressure equals the external pressure, then the liquid BOILS. You can therefore change the boiling point of a liquid by changing the "external pressure" upon it. This is why water boils at a temperature lower than 100° C at high elevations where the air pressure is less than normal.

On the other hand we can RAISE the boiling point of a liquid by subjecting it to HIGHER pressures than usual. This is how we get super-heated steam for boilers operating at high pressure.

We hope this brief chapter has given you some understanding of the kinetic-molecular theory of matter and how it relates to certain natural laws and effects. This is not a particularly easy theory to teach, but fortunately there are some excellent films on the subject which will be shown to you.

FOOD FOR THOUGHT:

1. What would happen to the molecules of gas in a container, and the pressure, if molecular collisions were NOT perfectly elastic?

2. Given a liter container full of hydrogen and a liter container full of oxygen, both at 20° C:

a. What can you say about the average kinetic energy of the molecules of both gases? ____________________

b. What can you say about the numbers of molecules of each gas, assuming the containers were filled at the same pressure? ____________________

c. Now think: what can you say about the average speed of the molecules in each container? ____________________

d. If you raise the temperature of the hydrogen container to +586° A, what can you say about its pressure compared with the oxygen container? ____________________

3. Will gold atoms diffuse faster or slower than sodium atoms? ____________________ Why? ____________________

4. Do you think that ALL molecular motion CEASES COMPLETELY at absolute zero?

5. If you could cool a gas to absolute zero, what happens to its volume?

6. What does a mercury barometer measure?

7. Why does a solute (like sugar, for example) dissolve faster in water when you stir it?

8. Why does a suspension of sand in water eventually settle out?

9. Would the particles in cigarette smoke be small enough to show Brownian movement? Will they eventually settle out? How could you find out these answers?

10. Do you suppose that you might be able to separate light molecules from heavy ones by means of different diffusion rates? Find out if this is ever done.

11. Could you think of any other explanation (besides kinetic-molecular theory) for the Brownian Movement? For diffusion of solid gold into solid lead?

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

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Special Chemistry Course Text

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CHAPTER 16--WATER, WATER EVERYWHERE, AND NOT A DROP TO DRINK

The above quotation from The Rhyme Of The Ancient Mariner is unfortunately becoming more true with every passing year. The Ancient Mariner was discussing the ocean, but modern factories and modern living are contaminating other water sources more and more heavily.

Water, of course, is a very common and abundant material. It is necessary to your life and mine, as well as to plant life. It is also a much more complicated substance than most people realize.

First of all, although water itself is usually a liquid, it is formed from two elements which are both gases. Water is a compound, and each water molecule contains three atoms--one of oxygen and two of hydrogen. It can exist in all three states of matter, as solid, liquid, and gas (vapor).

Although pure water is easily made by burning pure hydrogen in air or in oxygen, we rarely have it. Due to the very fact that it tends to dissolve so many other different things, it is usually contaminated with a large variety of other substances. These include dissolved gases, mineral or vegetable matter and suspended materials.

Water is used up, or formed, in many chemical changes. Conversely, many chemical changes do not take place on a practical basis unless at least small amounts of water are present.

Pure water does not act as a conductor of electricity. However, the addition of small amounts of "ionic" substances will make it a very good conductor.

Pure water does not "wet" things very easily, but the addition of small amounts of "wetting agents" (soaps, detergents) will permit water to wet substances faster and more completely.

A very large fraction of the earth's surface is composed of water, yet today industries and nations are literally starving for it. Water can be "soft" or "hard", "light" or "heavy", "saline" or "sweet", a curse or a blessing depending upon its distribution. It can either heat our homes and offices, or cool them. It is indeed a very useful and versatile compound. It is als, fortunately, still one of the cheapest.

Well, this is certainly one of the most interesting substances found in nature, so let us take a good close look at it:

THREE STATES OF MATTER:

We said that water can exist as a solid (ICE), liquid (WATER), or gas (WATER VAPOR). These are the three different "states" of matter, and the different "states" have different physical properties.

A lot of different elements and compounds can exist in different states of matter, but in every case, a change of energy is involved in going from one state to another.

For instance, in order to change ice into water (a physical change), you have to add energy in the form of heat. In order to go from water to water vapor (steam), you also have to add heat energy. If you did this in reverse, just as you might think, the system would have to give up heat energy in making the change of state.

This is very easy to show. Put a few drops of water on your hand, then blow on it. You are changing the liquid water to water vapor (a gas), and since this change takes up heat in the process, your hand feels cooler. This is how the so-called "evaporative coolers" work which are used in the homes and offices of the southwestern United States.

The reverse is also easy to show, but can be more painful. If you hold your finger in the steam (water vapor) coming from a boiling kettle, you will soon decide that the water will condense on your skin, and that heat energy is being given up in the process. (In this case, we do NOT recommend your trying the experiment.)

A similar change in heat energy is required for ALL substances when they change from one state of matter to another. The actual energy change required is different for different substances. In the case of water, it takes 80 "calories" of heat energy to change one gram of ice into one gram of water (called the "Heat of Fusion"), and it takes 540 "calories" of heat energy to change one gram of water into one gram of steam (called the "Heat of Vaporization"). From these values you can see right away why a person can get a bad burn from steam.

SUSPENSIONS AND SOLUTIONS:

Water is a good general "solvent". That is, it will dissolve many other substances to give what are called "solutions". When substances dissolve in water, their atoms or molecules tend to separate from each other, and to get as far as possible apart from each other. A solution is really a mixture in which the "components" of the mixture are of molecular dimensions.

We can have other mixtures in which the material is NOT that small. For example, you could take some fine sand and stir it into water. You would get a temporary mixture (called a "suspension") because the density of water and sand are not extremely far apart, but the sand will settle to the bottom after a while.

Since both of the above processes represent only a physical change, you can reverse them (and separate out all the components by physical methods. In the case of sand and water, pouring the suspension through a filter will permit the water to pass through, but keep back the sand. If you mixed together sulfur powder and iron filings, you could separate the mixture by running a magnet through the mixture. The magnet would attract and hold the iron, but have no effect on the sulfur particles.

In the case of solutions, the components are so well "mixed" that they can NOT be filtered out, but other methods of physical separation can be used. A solution of salt in water can be separated, for instance, by distillation. By adding heat to the system, in special equipment built for this purpose, we change the liquid water to steam, and then change it back again to liquid water, but since the salt does NOT undergo a similar change in state at the same temperature, it remains behand and is separated.

Another physical process that will separate suspensions is "centrifugation". We have all stirred a cup of coffee or tea containing a small amount of suspended material, such as coffee grounds. Have you noticed how the suspended solids tend to collect together towards the center bottom of the cup? By subjecting suspensions to much faster circular motion by means of electrically driven "centrifuges", we can speed up the process a great deal, and make much smaller particles settle out very quickly.

Centrifuges are frequently used in chemistry to separate suspended solids because it is much faster than filtering. They are also used in industry. For example, dairies separate suspended particles of cream from milk by this method.

The process of centrifugation will NOT separate true solutions (such as sugar in water) but only suspended materials.

Filtration is another method of removing suspended materials from a liquid. By now you will have already used this method in the laboratory. Again, filtration can NOT be used to separate the components of true solutions, such as salt in water.

Under a general discussion of solutions we must mention that many gases will dissolve in water (and in some other liquids) to form true solutions. When you uncap a bottle or can of soft drink, thus relieving the pressure, the bubbles which begin to escape are bubbles of carbon dioxide gas which were dissolved in the soft drink. The gas is put there in the first place to provide that "tingly" feeling when you drink it. When you boil water in an open vessel or in a glass vessel (so that you can see it), the hotter the water gets, the more bubbles appear. This is from air which was dissolved in the water.

From this example above what can you say about the solubility of air in water with regard to change in temperature? In general, all liquids will dissolve LESS of a gas at higher temperatures. This is just the reverse of the temperature effect on dissolving solids in liquids since usually you can dissolve MORE of a solid at higher temperatures.

The above difference can be very important to you. When you buy bottles of soda at the grocery store, they are already under fairly high pressure. What could happen if you leave them in your car sitting in the sun on a hot summer's day? Or put them near a hot stove at home? Under such circumstances a soda bottle can literally become a "bomb, and explode with a great force.

SOLUTION CONCENTRATION: For true solutions there are several ways of expressing the "concentration", or the amount of dissolved material present. Weight Percent is the number of grams of solute, per 100 grams of solution. Weight/Volume Percent is the number of grams of solute, per 100 ml of solution. This is very frequently used.

If we take one gram-molecular weight's worth of solute and put this in one liter of solution, we get what is called a "Molar Solution". This is a rather convenient concentration for the chemist to use because molar solutions will always contain the same numbers of molecules. You can, of course, have "fractions" of these solutions, such as 1/10 Molar, .05 Molar, etc.

The chemist also uses "Normal" solutions which relate to the concentrations of solutes which will react directly with each other. For example, 50 ml of 1 Normal HCl solution will react exactly with 50 ml of 1 Normal NaOH solution. At the moment this is all we need to know regarding Normal solutions.

In most tables and handbooks of chemical data solubility is given in terms of grams per 100 ml of solvent. The temperature must be specified since this affects the solubility of most substances.

IONIC AND NON-IONIC SOLUTIONS:

We said earlier that certain substances, when dissolved in water, will give a solution that will carry an electric current much like a piece of wire would do. Such substances give what we call "ionic" solutions, and the substances themselves are called "electrolytes". The salt you sprinkle on your food is an electrolyte. It appears that even in the solid form, before they are put into solution, the atoms of an electrolyte exist in some form that carries a small positive or negative electrical charge. Ordinarily, the charge is not apparent because the particles are so close to one another in the solid state that the total substance behaves electrically neutral in most situations.

However, when an electrolyte is dissolved in water, the water molecules (which we said are non-conductors of electricity by themselves) get between the small charged particles of the salt and permit them to drift much further apart from each other so that they now behave as separate positive and negative particles (which are called "ions").

There is very good proof of the existence of "ions" in water solutions of electrolytes because if we put a battery in series with such a solution the positively-charge ions go to the negative pole of the system, and of course the negatively-charge ions go to the positive pole. If the particular ions happen to give a colored solution, we can actually see this change taking place when we turn on the electricity.

Now the formula for table salt is Sodium Chloride, or in chemical shorthand NaCl. When we dissolve this substance in water, based on the ability of the salt solution to carry electricity, it appears that we do NOT have molecules of NaCl, NOR atoms of sodium and chlorine, but charged ions. As a diagram:

NaCl NOT this

Na Cl NOT this

But we do have: Na^+ and Cl^- (sodium ions and chloride ions)

In some cases the particle that carries the electrical current in a solution contains more than one kind of atom. This particular kind of a particle is called a "group", or a "radical", but it behaves exactly like the simpler ions having only one kind of atom. For example, the sulfate radical (or sulfate group) contains one sulfur atom and three oxygen atoms, but the entire group stays together as a charged particle bearing a double negative charge. Here is a partial list of such radicals or groups, and the charges they carry in solution:

SO_4^{--}	sulfate group	CO_3^{---}	carbonate group
PO_4^{---}	phosphate group	NO_2^{-}	nitrite group
NO_3^{-}	nitrate group	SiO_3^{--}	metasilicate group
CNS^{-}	thiocyanate group	SiO_4^{----}	orthosilicate group
SO_3^{--}	sulfite group	MnO_4^{-}	permanganate group

Note that most of the above "radicals" contain several atoms of oxygen in combination with non-metallic atoms.

Ionic solutions are used in the electroplating industry to put thin coatings of metals over other conducting materials. The pretty and shiny bumper on your family auto is a piece of steel with a thin coating of chromium metal. Besides a fancier appearance the chrome coating protects against rusting since steel does rust, but chromium does not. Could we use gold instead? Or silver? What would be one of the chief reasons against the use of these two metals for plating auto parts?

In contrast to electrolytes which dissolve in water to give ionic solutions that can carry an electrical current, there are many other substances that dissolve in water also, but do NOT do this. These substances are called non-electrolytes. Sugar, alcohol, acetone are examples of non-electrolytes. Most of the substances which do NOT give ions in solution belong to a special branch of chemistry which will be mentioned much later in this course.

COLLOIDS: Between coarse suspensions (such as sand in water) and true solutions (such as sugar in water) there is an in-between state of affairs. In this case the particles are larger than molecular dimensions so we are not dealing with a true solution; but they are not large enough to be visible to the eye or settle out.

Mixtures of this type are called "colloids" or sometimes (erroneously) "colloidal solutions". They form a very important class of materials and they have some unusual properties. Colloids themselves fall into two classes: lyophobic (water-hating) and lyophilic (water-loving).

Almost any material can be put into a colloidal condition, or be made to form a colloid. Metals, such as gold and silver for example can be put into finely divided form by precipitating them from solution under the proper conditions to form particles of the right size, and will then become a metallic colloid. Such colloids can last for many years even though the density of gold or silver is much greater than that of water, and you might expect them to settle out.

The lyophilic colloids, such as glue, gelatin, or skin have densities close to that of water itself. They, too, can be stable for many years.

Usually the particles of a colloid are electrically charged. This charge is thus mutually repelling and prevents them from coming too close together and settling out as larger particles. The charge may be part of the colloidal material itself, or it may be picked up from some electrolyte in the same "solution". Therefore, if the colloidal particle is stable because of an electrical charge, then neutralizing this charge would permit the particles to get close together, build up into larger particles, and finally precipitate out.

Colloids can NOT be separated by the usual methods of filtration because the particles are too small for that. However, in recent years ceramic filters with especially tiny openings have been used, and they will hold back the colloidal particles and separate the colloid. This process is called "ultra-filtration", and is used mostly in the manufacturing of medical products such as vaccines.

Colloids play a large and useful part in industry and everyday life because many materials which will not form a true solution can still be put into a solvent in colloidal form. Mayonnaise or salad dressing are colloids. Soaps are colloids. Drilling muds used in drilling for oil are colloids. Many adhesives are colloids, including animal glue and mucilage.

Colloids as a class have some unusual properties. For example, the color of a colloid is more likely to be a function of particle-size than an inherent physical property of the colloidal material. A solution of a copper compound will always be blue or blue-green due to the fact that the copper ion has this color in solution, but a gold colloid in water may be blue, green, red, or brown, depending upon the size of the gold particles.

We will point out more about colloids in other chapters as we find them applying there.

We have mentioned vapor pressure in its relation to boiling point. What do you think would be the effect of a solute on the vapor pressure?

At this point your teacher will lead a discussion on the effect of solutes on the vapor pressure of a liquid in terms of kinetic-molecular theory.

All right, you can imagine that molecules of a solute actually "get in the way" of water molecules attempting to escape from a sugar solution into the vapor phase. To overcome this interference you would have to put in MORE ENERGY than usual in order to raise the vapor pressure high enough to equal the external pressure (boiling point). In order to give the water molecules this increased energy, you would have to do it by raising the temperature which would make the water molecules have a higher average speed and energy.

This is exactly what happens. Any solute in water depresses (lowers) the vapor pressure of the solvent. Therefore, the solution will have a higher boiling point than the pure solvent alone.

The amount by which the boiling point of a solution is raised (over that for the pure solvent alone) depends directly on the number of interfering solute particles. Thus, it depends upon the concentration of solute. It also depends upon whether the solute is IONIZED or not. One molecule of electrolyte used as a solute may break down into two or more ions, each particle of which can interfere with solvent molecules, and thus cause an increase in the boiling point.

We find this is actually the case, and that electrolytes give increases in the boiling point which depend upon BOTH their concentration and the number of ions formed in solution. WHAT A MARVELOUS DIRECT PROOF OF THE EXISTENCE OF IONS IN SOLUTION.

If we take one gram-molecular-weight's worth of ANY chemical material, we already know that we are taking the SAME NUMBER OF MOLECULES (Avogadro's Number). Therefore, from all of the above, we would expect that this amount of ANY solute would raise the boiling point by the SAME AMOUNT. This is true for all non-electrolytes, and true for electrolytes also if we take into account the number of ions formed in solution.

To take some examples of non-electrolytes first: One gram-molecular weight of sugar (sucrose) is 342.30 grams. One gram-molecular weight of ethyl alcohol is 46.07 grams. One gram-molecular weight of glycerine is 92.09 grams. If we weigh out these quantities of each solute and put them each in 1000 grams of water and raise the temperature of each solution until it boils, the boiling point will NOT be 100.0° C., but it will be +100.512° C. IN EACH CASE.

This shows that the type of solute molecule has no particular effect, but that only the number of them present makes a difference.

In the case of sodium chloride (NaCl) the gram-molecular weight is 58.45 grams. If we weigh out this amount and dissolve it in 1000 grams of water and raise the temperature until boiling occurs, we will find that the solution boils at +101.42° C. This is exactly TWICE the rise in boiling point noted for our three non-electrolytes, but since in water solution the sodium chloride exists as separate sodium and chloride IONS, then we can see why the boiling point should be twice as great as for a non-electrolyte.

An exactly similar case exists for the change in freezing points of solutions. Interfering solute molecules in a solution literally "get in the way" of the solvent molecules trying to form their customary stable solid arrangement, and thus tend to prevent formation of a solid unless LOWER than normal energy requirements are met. Thus the solutions will NOT freeze at the usual freezing point of the pure solvent, and the temperature must be lowered further.

Again, as in the case of boiling points, the relative concentration and the number of the interfering solute particles is what determines the degree of freezing point lowering. For one gram-molecular-weight of any non-electrolyte dissolved in 1000 grams of water it will lower the freezing point to -1.86° C. Thus, our three solutions of sugar, alcohol, and glycerine would all freeze at -1.86° C.

Our solution containing sodium chloride (NaCl) would freeze at -3.72° C.

Kinetic-molecular theory and ionic theory thus provide a good and reasonable explanation for the change in freezing and melting points of solutions as different from those of the pure solvents alone, and both for non-electrolytes and electrolytes.

COMPOSITION OF WATER:

Chemically, water is a compound of hydrogen and oxygen, both of which are normally gases. Since the "valence" of oxygen is minus two, and the valence of hydrogen is plus one, it takes TWO atoms of hydrogen to combine with one atom of oxygen. In chemical shorthand we would write the equation for hydrogen combining with oxygen as:

$$2\ H_2 + O_2 \dashrightarrow 2\ H_2O$$

The composition of water is easy to prove. If we burn hydrogen gas in air or in pure oxygen, we get water. If we mix hydrogen gas and oxygen gas together and ignite the mixture, it will react so quickly that you get an explosion, but the product is also water. From the other direction, if you take water and take it apart by means of an electrical current, you get back both hydrogen and oxygen gas.

When hydrogen gas and oxygen gas combine to produce water, we find that it takes TWO volumes of hydrogen to react with ONE volume of oxygen. IF equal volumes of gases actually contained the same number of gas molecules, then this is exactly the volume ratio which you would expect from looking at the above equation. Many years ago an Italian scientist discovered this very fact.

Avogadro's Law states that "Equal volumes of gases (under the same conditions of temperature and pressure) contain the same numbers of molecules". The statement about temperature and pressure had to be put in there because the volume of a gas depends upon these two conditions.

You already know that some metals, like iron, can combine with oxygen (usually from the air) to form "oxides". Rust is iron oxide. The choking gas from a smelter smokestack is sulfur dioxide. Water can be looked at, chemically, as "hydrogen oxide".

NATURAL WATER: Nature does not provide us with the purest possible water. Soluble materials in the earth usually dissolve in underground water, or in the water from lakes and streams. Ocean water has a large variety of different substances dissolved in it, and mankind is constantly adding impurities, as the result of manufacturing process, to his water supply.

Thus, modern man has a larger struggle in the years ahead to find enough pure water to drink, wash his clothes, and supply his needs in industry.

HEAVY WATER OR LIGHT WATER? It has been mentioned already that one of the important sub-atomic particles is called the "NEUTRON". Remember that the neutron has mass (weight), but no electrical charge.

Quite a few of the elements can exist with a different number of these "neutrons" in the nucleus. Now, if that happens, just what properties would that affect?

1. Chemical Properties? No, because chemical properties depend mostly on the number and arrangement of electrons

in the outer shell of the atom.

2. Physical Properties? Well, it would certainly change the MASS, or WEIGHT, of the atom. Therefore, it would certainly affect any physical properties which depend upon weight, such as:

a. Molecular weight
b. Density
c. Refractive Index
d. Diffusion
Etc.

These atoms which have a different mass, but otherwise identical chemical properties, are called "ISOTOPES". They can be very useful in following chemical reactions, and in other ways.

The best example of "isotopes" is seen with our lightest element hydrogen. Hydrogen itself, as you have learned already, has ONE PROTON in the nucleus, and ONE ELECTRON orbiting around it, but the nucleus can also hold a neutron which would add extra weight. In this case, the atomic weight = 2.00, and the isotope is called "DEUTERIUM".

The hydrogen nucleus can also hold another neutron, giving an atom with an atomic weight of 3.00, and in this case the isotope is called "TRITIUM".

It is not easy to separate isotopes from one another since they undergo exactly similar chemical reactions. Separation must be accomplished by methods based on the rather small difference in mass of the atoms. Diffusion of gases is one of the methods used.

Most of the elements exist as more than one isotope. Therefore the commonly accepted atomic weights given in your charts and tables are actually averages for that element. Hydrogen, for example, is given as an atomic weight of 1.008 because most of it exists as hydrogen itself, and only a small proportion as deuterium or tritium.

Actually then "heavy water" is water made from deuterium or tritium instead of ordinary hydrogen, and it IS heavier (more dense) than ordinary water.

PURIFICATION OF WATER:

Since in many cases the everyday water supply is contaminated, the water must be purified before use. The process used in purification depends upon (1) what kind of contaminating substances are present, and (2) the purpose for which the water will be used.

If the water contains suspended matter, such as sand and dirt, this is easily removed by filtration. If the water contains dissolved substances, they might be removed by distillation or by different kinds of chemical treatment.

Distillation is an expensive process on a large scale. Distillation does not remove volatile impurities, such as ammonia, since such impurities would distill over with the water itself.

Chlorine, a disinfectant gas which you will meet later in this course, is one of the chemicals frequently used to purify water. It can be used directly, or in the form of some compound which will give up "free" active chlorine gas when it comes in contact with water.

The usual method of purifying water for home purposes is to render it clear from suspended materials by settling, filtration, or chemical action, then purifying it with disinfectant chemicals, then usually "aerating" it to get rid of the taste of such chemicals. To "aerate" water it is simply sprayed into the air and sunlight through large nozzles.

Industry frequently has to purify its own water. For example, any industry that uses large amounts of water in steam boilers has to remove the chemicals which cause "scale" to form in their boilers, otherwise the boilers would give trouble. This scale is the same substance that forms on the inside of your teakettle at home, or inside your mother's steam iron. Compounds of the elements calcium and magnesium, found so abundantly in nature, are responsible for the so-called "hard water" which causes this scale. Removing these calcium and magnesium compounds gives us "soft water" which is easier on equipment and better for washing clothes.

A type of chemical change called an "ion exchange reaction", using either natural or artificial substances, can take out the compounds which cause hard water, and make it fit for use in industry and for washing. You may have some kind of device that does this at home if you live in an area where the water is very "hard".

When water is stored for long periods of time, even in glass bottles, it may change slowly. This is especially true when other chemicals are present, such as medicines. Since the change may be unexpected, and may produce substances that are more harmful, by chemical reaction, that is one reason to throw away medicines before they get too old in your medicine cabinet. The change is due to the fact that glass itself dissolves very slightly and very slowly in water.

Water is such a common material that scientists use it as the basis of the physical property called "specific gravity" (which is almost the same as "density"). The density of a substance is its weight per unit volume, and it is a very useful and easily taken property. So water, which weighs close to 1 gram per milliliter, thus has a density of 1.0. Any substance which floats in water has a density of less than water itself, and any substance that sinks in water has a greater density than water itself so this gives us a very quick and easy method of establishing a rough density value for any unknown material. By more careful measurements by a variety of methods we can obtain more accurate values for density.

This means of flotation provides a simple method which is used to measure the amount of antifreeze in your auto radiator in wintertime. Since the liquid substances used for this purpose have a different density than water, the density will change, depending upon just how much antifreeze you have added to your cooling system. By means of a hydrometer we suck up a few ounces of radiator fluid and determine the height to which a small glass "float" will be raised. Numbers marked on the float can be read directly in terms of percent of antifreeze, and in terms of how much protection against freezing has been provided.

Water is, of course, needed to make plants grow. The problem here is to get enough water to meet the need in different areas, especially dry ones. In dry areas we usually have to pump water up from beneath the ground from wells. This takes costly equipment and maintenance so even then the water is not provided free. In most cases, land is bought and sold for different values depending upon the "water rights" that go with it.

The future of this country depends in some measure upon man's ability to recover pure water from the ocean cheaply and in large quantity.

Well, it has turned out that water is not nearly as simple a material as we thought. After this chapter, you should know a lot more about it and its properties, and how the chemistry of water affects your life whether you drink it, take a bath in it, or put it in your radiator.

FOOD FOR THOUGHT:

1. One of the growing problems of the modern world is the build-up of detergents in our drinking water supply. What could be done to handle this problem? Do you know of any steps that are being taken on this problem at the present time?

2. Have you heard about, or read about, the effects of industrial "pollution" of stream and lake waters on natural fish life? What effect could this have in terms of mosquito population?

3. Discuss the possibility of using sodium chloride (salt) or phosphoric acid (H_3PO_4) as antifreeze materials for auto radiators from the viewpoint of cost, freezing point lowering efficiency, and other factors.

4. Discuss the advantages and disadvantages of using alcohol (wood alcohol, CH_3OH) as an automobile antifreeze.

5. Discuss the advantages and disadvantages of using glycerine as an auto antifreeze.

6. What would happen to the fish in a lake in below freezing temperatures if the density of ice were larger than that of water, instead of being lesser?

7. Can water go directly from the solid to the vapor state? Have you ever dried clothing outside in below freezing temperatures?

8. Large cities frequently add ferric chloride to their water supply before settling or filtration. Discuss WHY this is done.

9. Large cities frequently "aerate" their water supply. WHY do they do this and in what step in their treatment process does it take place?

10. Is "heavy water" really more dense than regular water?

11. Discuss in class whether your community has any treatment plant or process for water.

12. Discuss in class whether your community has "hard" or "soft" water. If the water is "hard", is anything done to render it "soft"?

13. What is the one large common advantage in dealing with MOLAR, MOLAL, and NORMAL solution concentrations?

14. Discuss in class TWO direct pieces of proof that electrolytes actually DO exist in solutions as IONS rather than uncharged molecules.

15. Industry uses a piece of equipment called a "Colloid Mill". Without knowing anything more about it, what would you think its primary purpose is?

16. If a certain concentration of solute in water gives a solution which will freeze at -1.2° C, can you predict what the boiling point of that solution would be? What is it?
____________________° C.

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 17--HEAT AND CALORIMETRY

Heat energy plays a very important part in your everyday life. In most cases, this heat energy comes from a variety of chemical reactions. Gasoline is burned to drive your car; wood, coal, or gas is burned to heat your home and school; the food you eat is reacted during digestion to provide heat for your body (as well as mechanical energy). You have learned already that ALL chemical reactions involve heat energy changes, either giving off or taking up heat on a "quantitative" basis.

Such heat changes during a chemical reaction can be measured in a device called a "calorimeter". The basic unit of heat energy in the metric system is the calorie. The calorie is the amount of heat energy required to raise the temperature of one gram of water by one degree Centigrade.

Since water is so common and cheap, it is used as the basis of many scientific measurements such as the above. In actual practise, then, we can react some material in such a way that the heat change involved is transferred to the water, and measure the amount and change in temperature of the water.

The Specific Heat of any substance is the number of calories required to raise the temperature of one gram of the substance by one degree Centigrade. You should know that the Specific Heat of any material will vary slightly depending upon the temperature range involved (including water itself). However, it does not change very much, and for practical purposes we can assume that the value is constant for any particular material.

At this point we should mention again the distinction between TEMPERATURE and HEAT. Temperature is a "quality" whereas heat is a "quantity" concept. The transfer of a quantity of heat may involve temperature changes, but temperature alone is NOT enough to define a heat quantity. This difference is not always easy for the student to understand.

Our bodies have a built-in heat control system which keeps us operating at one certain temperature, regardless of the external temperature. Of course if we are subjected to extreme conditions, this may put a strain on our system. Therefore, we try to live under conditions of reasonably constant temperature. Since these bodily systems depend upon "evaporative cooling" for their operation, they are partly dependent upon the humidity of the surrounding air; and for comfort this may require a certain measure of control also.

Our chief source of heat energy is the sun. Despite the approximately 93,000,000 miles separating us, the nuclear reactions that take place there provide the earth with tremendous amounts of heat energy. Besides chemical reactions, other more common sources of heat energy are: electricity, friction, and the compression of gases.

One of the common effects of a change in temperature of a piece of material is a change in size. Since according to the kinetic-molecular theory the molecules of a material vibrate more vigorously at higher temperatures, they obviously occupy (on the average) more space. Solids, liquids, and gases in general all expand (get larger) when heated. This property has useful applications, one of them being the "thermostat". The thermostat may be made from a bar consisting of two different metals riveted together which bends with changes in temperature, thus closing or opening an electrical switch or a gas valve. A gas filled glass container of the right design could be used also to make a thermostat.

Most auto engines have a thermostat in their cooling system which prevents the water in the radiator from circulating until the engine has warmed up to a certain temperature.

Heat energy can be moved, or transferred, from one place to another by three different ways: 1. conduction, 2. convection, 3. radiation. The energy from the sun reaches us through the third method (radiation) in much the same way as does the visible light from the sun. We will learn more about this later.

The first two of the above methods of transferring heat energy involves matter in direct contact. For example, if you heat an iron bar about a foot long at one end only, you will soon have to let go of the other end. The heat has "travelled" along the iron bar by "conduction". If you light a stove in one corner of a room, the heated air will rise, sucking in cooler air from near the floor. This will form a pattern of moving "convection currents" which will soon heat the entire room to a fairly uniform temperature.

Chemists are interested in materials which are "good" conductors of heat, and also in those materials which are "poor" conductors. Wood is a "poor" conductor. Therefore, we can hold a test tube of boiling water in a wooden clamp, or hold safely the wooden handle of a boiling kettle without getting burned. Since gases are, in general, relatively poor heat conductors, they therefore make good "insulators". Plastics, too, are frequently good insulators.

In recent years the chemist has combined the qualities of plastics and gases in regard to heat transfer in a "foamed plastic" which is finding widespread uses in heat insulation. Another use of the same type of foamed material is in packaging for delicate objects since the material is a good insulator against mechanical shock also. Small portable refrigerators and "ice chests" use these materials which are a product of the chemists' imagination.

As you may learn in a course in physics, radiated heat can be "reflected back" on itself just like visible light by highly reflective surfaces. Many house roofs today are painted with a thin layer of aluminum paint to form a reflective coating. These houses are cooler in summer because they reflect a high percentage of the sun's heat. Similarly, gasoline storage tanks (or chemical storage tanks) should be painted with highly reflective materials (such as aluminum coatings) to keep the temperature as low as possible for the contents. A light colored auto will be also cooler in the summertime.

The chemist (and other scientists) frequently make use of a heat insulated container called a "Dewar" flask. The everyday "Thermos Bottle" is a common variety of the same type. It consists of two thin walled glass bottles, one within the other. The in-between space is a vacuum. Because of the vacuum (and the poor heat conductive properties of glass) the contents will undergo very little change in temperature due to conduction. Therefore, hot contents will stay hot, or cold contents will stay cold.

A Dewar flask (or a thermos bottle) can make a very simple and fairly accurate "calorimeter" for measuring specific heats of materials, or for measuring "heats of reaction" for certain chemical reactions.

In the case of measuring "specific heat" of a material, the calorimeter can be partially filled with a weighed amount of water, and its temperature taken and recorded. A weighed amount of the materials (lead shot, or copper shot, for instance) can be heated to a higher temperature, and its temperature taken and recorded. As quickly as possible (so that as little heat as possible is lost) the material is transferred to the Dewar flask (or thermos bottle), shaken a short period of time to make the transfer of heat uniform, and the temperature again taken and recorded.

From the change in temperature of the water and the amount of water in the system, one can determine the number of calories transferred from the other material. Dividing by the weight of the material will give the specific heat.

In the case of chemical reactions, care must be taken to relate the amount of heat evolved (or taken up) to the proper atomic or molecular weight through using a balanced equation to represent the reaction taking place.

For example, for the burning of carbon to give carbon dioxide:

$$C + O_2 \dashrightarrow CO_2 + \text{HEAT}$$

Whatever weight of carbon is used should be related to 12.000 grams which is the gram atomic weight of carbon, and the amount of heat evolved also related according to the same ratio.

Where a chemical reaction involves the formation of a compound from its elements, the amount of heat involved is called the "Heat of Formation". As we have already seen in previous chapters, then the Heat of Formation of water is + 119,200 calories. This means that when 4.032 grams of hydrogen are burned with 32.000 grams of oxygen to produce 36.032 grams of water, the reaction will also liberate, or produce 119,200 calories of heat energy.

All chemical substances either liberate or take up heat energy when they are dissolved. When we use water as the solvent (as we usually do), and one molecular weight of solute, we call this energy change the "Heat of Solution". This heat of solution can be quite large, especially for ionic solutes.

In most cases heat is liberated (given off) when chemical materials are dissolved in water (positive heat of solution). Ammonium salts are notable exceptions to this general rule.

The chemist (or other scientist) frequently wants to achieve very cold temperatures. Remember the cooling effect of blowing across your wet hand? We can achieve very low temperatures by using the same effect, but other materials instead of water. And by generating such colder temperatures, we can make substances change to the liquid state which would ordinarily be gases. Hydrogen and oxygen are examples of common gases which can be liquefied at very low temperatures. In turn, by allowing these gases to expand very rapidly we can achieve still lower temperatures. This is the method by means of which scientists have been able to come very close to ABSOLUTE ZERO temperatures, and to study the behavior of different materials and reactions at low temperatures.

Instead of blowing on the palm of your wet hand, sophisticated mechanical devices are used to move heat energy from one place to another. There is one in your refrigerator. There may be another one cooling your home or school in the summer. You may have a portable unit in your car. These are literally "heat engines", but however sophisticated they seem to be, they all work on the same principle.

In recent years much work has been done on "solar furnaces" which can get to very high temperatures. Another possibly useful future idea is that of heating homes in winter, and cooling them in summer, by means of chemicals in solution. This idea is based on the "Heat of Solution" principle discussed above, plus means for storing and circulating the fluid to get the desired temperature effects.

FUELS: To be used as a common heating or cooking fuel a material must meet certain special requirements:

1. It must be quite cheap.
2. It must be readily available.
3. It must have a fairly high Heat of Reaction.
4. It must be capable of being controlled.
5. It must have a minimum of waste products.
6. It must have a waste product of fairly low toxic properties.

Wood, coal, or coke have been used to a great extent in past years, and still are in some localities. Recently the building and maintenance of pipe lines have enabled many of us to utilize natural gas from the wells of Texas and other states. In some instances (rural homes) gas is "bottled" and sold to the consumer for heating and cooking purposes.

Gas is very convenient, but is itself quite toxic. In case of an unknown leak, it can be a terrible explosive hazard. In some cases of extreme cold weather, gas can "freeze" (actually, a few drops of water may freeze instead) in the line and cause a temporary obstruction to gas flow. The flame of course will go out. When thawing occurs, the gas starts to flow again. In a heating device which is not "protected" by means of automatic cut-offs, etc. gas could then escape unknown into the room and cause an explosion or asphyxiation.

Since natural gas is a mixture, the more volatile gases will boil off first. This causes some change in pressure. In order to maintain a uniform pressure to your heating or cooking appliances, a device called a "regulator" is provided which helps to maintain a constant pressure of gas. Gas in the tank is at a higher pressure, and the pressure is lowered and kept to a more uniform level as it passes through the regulator.

Some fuels are "cleaner" than others with regard to waste products. The large cities burning soft coal throw thousands of tons of waste materials into their skies for their citizens to breathe. Also, the disposal of burnt ash and "clinkers" is a vast problem in a large city. Again, gas has very little "waste" in comparison.

FOOD FOR THOUGHT:

1. Feel the metal parts of your school desk, and feel the wooden parts. Is there any difference in apparent temperature? If so, WHY? Is there any real difference in their temperature?

2. Considering its approximate density and its physical structure, why should wood be a better heat insulator than iron?

3. Considering its approximate density and its physical structure, why should foamed plastic be a better heat insulator than wood? If necessary, get a foamed plastic "heat cup" and tear it apart to look at it.

4. A thermos bottle calorimeter contains 50 grams of water at a temperature of 20° C. A piece of metal weighing 25 grams is heated to a temperature of 80° C, then quickly placed in the calorimeter. After shaking to achieve a uniform temperature, the final temperature of the water plus metal is 24° C.

a. What is the temperature drop for the metal? _____° C.

b. What is the temperature gain for the water? _____° C.

c. How many calories of heat were transferred to the water? ________ cals.

d. How many calories per gram did the metal lose? _____________ cals/gram

e. What is the Specific Heat of the metal? _________ cals/gram

5. If you dissolve some potassium hydroxide in water, the solution gets hot. This means that:

a. Heat is taken up?

b. Heat is given off?

6. If you dissolve some ammonium chloride in water, you expect a negative heat of solution. This means that:

a. The solution will feel colder?

b. The solution will feel hotter?

7. If you allow iron to turn slowly to iron oxide (to rust), or burn it quickly in pure oxygen, is there any difference in the Heat of Formation of the iron oxide formed?

8. Does the speed of a chemical reaction have any effect on the Heat of Reaction for that chemical reaction?

9. Would milk work about as well as water in the "evaporative coolers" used as summer air conditioners in New Mexico? Discuss the drawbacks (if any) of using milk instead of water.

10. If you wanted to run your "evaporative cooler" in the winter time, could you add some glycerin as an "antifreeze" to prevent the water from freezing up?

11. Could you use 100% glycerin (no water) in an "evaporative cooler" instead of water?

12. What effect would a "catalyst" have on the "Heat of Reaction" of a chemical reaction, or on the "Heat of Formation" of a compound formed by a chemical reaction?

13. What happens to the heat that is removed from the inside of your refrigerator?

14. If two trains, both going sixty miles per hour, meet in a head-on collision on the same track, what happens to most of their kinetic energy (energy of motion)?

15. What is "dry ice"? Does it melt? Does it leave any residue?

16. In extremely cold weather, how could you best protect your gas lines:

a. Wrap only the "regulator" with insulating material? Why?

b. Wrap only the gas lines with insulating material? Why?

17. A certain compound has a gram-molecular weight of 40.0 grams. 20.0 grams of this compound were dissolved in 100 grams of water at 20° C, and the temperature of the solution was raised to 56° C.

a. How many calories of heat were evolved by the solution process? ____________ cals.

b. What is the Heat of Solution of the compound?
_____________ cals.

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In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 18--ACIDS, BASES, SALTS, AND INDICATORS

You have become acquainted already with a few of the common "acids" (such as hydrochloric acid) and "bases" (such as sodium hydroxide). These two chemicals are typical representatives of these two general types of substances. There are certain factors common to all "acids", and certain factors common to all "bases". We shall discuss these things in this chapter.

All so-called acids have certain chemical properties in common. For instance, they will turn a dye substance called "litmus" from blue to red. They all have a "sharp" sour taste (like vinegar). They all react with the general class of materials called "bases", and when they do, they always form water, and a "salt". They always conduct electricity. They always generate hydrogen gas when an electric current is passed through a concentrated solution of the acid.

It has been found that most of the acids are formed when a non-metal reacts with oxygen to form an oxide, and the oxide is then combined with water. For instance, burning sulfur in air gives a gaseous oxide, sulfur dioxide. Sulfur dioxide, when dissolved in water, gives all of the reactions of a typical acid due to the formation of sulfurous acid. As you already know, sulfur can react also with oxygen (or air) in the presence of a catalyst to give another oxide called sulfur trioxide. (This is a white solid instead of a gas.) Sulfur trioxide, dissolved in water, gives our familiar and useful sulfuric acid.

Phosphorus, another typical non-metal, also burns in air to give several oxides (depending upon the valence of phosphorus in the molecule). When dissolved in water, these oxides give us phosphorous acids.

Let us take a look at the common laboratory acids:

HCl	Hydrochloric Acid	HNO_3	Nitric Acid
H_2SO_4	Sulfuric Acid		
		HC_2H_3O2	Acetic Acid
H_3PO_4	Phosphoric Acid		

Looking at the formula next to each name, which was derived as you know from an actual analysis of each compound, you will notice that the only single factor common to all these acids is the presence of hydrogen.

When these acids are placed in water, they ionize, or break down into "ions". In the case of all of the above acids, the one common factor is the presence of hydrogen ion $H+$, and this ion is responsible for the behavior of acids. Incidentally, some acids break down to a greater degree than others, and thus furnish a higher percentage of hydrogen ions. These therefore are called "strong" acids. Of the above list, hydrochloric, sulfuric, and nitric acids are all "strong" acids.

A "weak" acid is one which does not break down into ions in water solution to as great an extent. It therefore does furnish hydrogen ions, but not as many as a strong acid. Acetic acid, phosphoric acid, and sulfurous acid are all "weak" acids.

What would you predict about the current-carrying ability of solutions of strong acids compared with that of weak acids?

So that you do not get a false impression, even strong acids are not 100% ionized in solution. There is always a fraction of the substance which is NOT ionized, and this fraction depends upon the nature of the solute, the nature of the solvent, the concentration of the solution, the temperature, and other factors. The picture is also slightly more complicated than has been mentioned so far in that the hydrogen ion is attached to water molecules (one or more), and then called a hydronium ion. However, the basic behavior is as described.

Let us turn our attention to "bases". Again, we find certain chemical properties in common such as:

1. Bitter taste
2. Turn red litmus paper to a blue color
3. React with acids to form water, and a "salt"
4. Conduct electricity in water solution

Typical "bases" are formed when metals react with oxygen to form an oxide, and these oxides are reacted with water. For example, sodium or potassium metal will react with oxygen (or air) to form sodium oxide or potassium oxide. Dissolved in water, these oxides yield the corresponding "hydroxides" which are the bases. By the way, the terms "base" and "alkali" mean the same thing in chemistry.

If we take a look at some of the common laboratory bases:

$NaOH$	Sodium Hydroxide	$LiOH$	Lithium Hydroxide
KOH	Potassium Hydroxide	$Fe(OH)_3$	Ferric Hydroxide
$Ca(OH)_2$	Calcium Hydroxide		

we see that the only common factor in the above formulae is the OH^- group or radical. This group is responsible for the behavior of the compound as a "base" or alkali, and is called the "hydroxyl group" or the "hydroxyl radical".

Like acids, those bases which seem to ionize or break down to give the largest concentration of hydroxyl ions in water solution are called "strong" bases. Lithium, sodium and potassium hydroxides are all "strong" bases. Those bases yielding relatively low concentrations of hydroxyl ions are called "weak" bases, and calcium and ferric hydroxides come under this class of bases.

Since the majority of useful chemical reactions involving acids and bases are reactions between ions, the "strong" acids and bases are naturally the most reactive. Sulfuric acid and nitric acid are both violent poisons, and attack the flesh very quickly. In contrast, we actually eat vinegar, which is a dilute solution of acetic acid, and small amounts of phosphoric acid are used in making the "phosphate" drinks at soda fountains.

Hydrochloric acid, despite the fact that it is a strong acid, is actually found in our bodies. It is manufactured by the body and used in dilute solution in the stomach as a digestive acid to chemically react with the food we eat and render it useful to us.

Again, the strong bases such as sodium or potassium hydroxides are violent poisons, and attack flesh very quickly. It is interesting to note that calcium and ferric hydroxides are considered "weak" bases primarily because they are both very insoluble, and thus CANNOT furnish many ions in solution.

The familiar "milk of magnesia", which is a suspension of very insoluble magnesium hydroxide, is used to react with excess stomach acid.

We have mentioned already that acids and bases react with each other to form water and a "salt". This particular type of chemical reaction is called "neutralization", and is very useful to us in many ways. The ordinary table salt you use at mealtime is an example of this particular class of chemical materials. This one, sodium chloride, was formed by the neutralization reaction of sodium hydroxide and hydrochloric acid, giving this particular "salt". Water is always formed in a reaction between an acid and a base also.

How can we tell when a neutralization reaction is complete? In other words, how can we tell when, for a certain amount of acid, we have added just enough base to neutralize it? You have already seen that litmus, a dyestuff, can change color depending upon whether it is placed in contact with an acid or a base. There are other colored substances which do the same thing. We call these "indicators", and some of them are extremely sensitive to very small amounts of acids or bases (to hydrogen ions or hydroxyl radicals). We can and do use these indicators to tell us when a neutralization reaction is exactly completed.

Since some of the common acids and bases are encountered in daily life, let us look at the best ways of treating emergency situations regarding them. Suppose that a person accidentally swallowed some sulfuric acid from an auto battery. Theoretically, it could be neutralized by giving him sodium hydroxide (lye), However, you would have no way of telling if you gave too much or too little, and an excess of lye would be just as bad as the acid. In a case like this, we give a "weak" base, such as sodium carbonate or sodium bicarbonate (baking soda). Either one of these will neutralize the strong acid, but an excess of the weak base would do no great physical harm.

Suppose that a person accidentally swallowed some lye (sodium hydroxide, a frequently used cleaning product around the home). Again, theoretically it could be neutralized by giving nitric or sulfuric acid, but again you would have no way of knowing whether you gave too much or too little. Therefore, the "cure might be worse than the disease". Here again we must administer a "weak" acid so that while it will neutralize even a strong base, an excess of the acid itself would do no harm. Dilute acetic acid (vinegar) is an excellent material for this purpose, and is of course usually found in the home.

A doctor could be (and should be) called afterwards, but in the above type of emergency, as in certain others, EVERY SECOND COUNTS, and emergency treatment RIGHT AWAY is worth a hundred specialists later.

A word here about acids or bases in the EYE. The eye is a very delicate and sensitive organ, and bases are even more potentially harmful to the eye than acids. In the case of acid or base getting into the eye, one cannot afford to wait even the few seconds to hunt up and use a possible neutralizing chemical. The answer here is to IMMEDIATELY FLUSH THE EYE WITH LOTS OF COLD WATER. Water is always the handiest liquid available, and will instantly serve to DILUTE the offending chemical to the point where it could not do much damage. But the essence of this treatment is SPEED. One second may mean the difference between a harmless experience and permanent damage.

Since we are on the subject of eyes, it is a good place to note that certain detergents can also be VERY HARMFUL to the eyes, and that modern detergent-based shampoos and other similar products should NOT be allowed to get into your eyes. Again, the immediate treatment would be to flush the eye with lots of cold water.

The above situation could occur in a laboratory, but the home is also a place of potential danger, and many common household products contain caustic, corrosive, or otherwise dangerous chemicals. You should avoid having them around the house, if possible. But if they are around, at least you should know how to give emergency treatment for such chemicals in case of accidental swallowing or skin or eye contact.

We have learned, so far, that an acid is a substance which furnishes hydrogen ion (or hydronium ion H_3O^+) in solution, and that a base is a substance which furnishes hydroxyl groups in solution. It is the reaction of these two groups which is the basis of the neutralization reaction, water and a "salt" always being formed. A simple example of this is the reaction between hydrochloric acid and sodium hydroxide:

(1) $HCl + NaOH \dashrightarrow H_2O + NaCl$ (a salt)

Other common neutralization reactions are:

(2) $H_2SO_4 + 2\ KOH \dashrightarrow 2\ H_2O + K_2SO_4$
(potassium sulfate, a salt)

(3) $2\ HNO_3 + Ca(OH)_2 \dashrightarrow 2\ H_2O + Ca(NO_3)_2$
(calcium nitrate, a salt)

(4) $H_3PO_4 + 3\ LiOH \dashrightarrow 3\ H_2O + Li_3PO_4$
(lithium phosphate, a salt)

Notice that in some cases it takes one molecule of acid to neutralize one molecule of base (Equation 1), whereas in others it takes two or three (or even more). This is because some of the acid or base molecules have more than one hydrogen ion or hydroxyl group, and thus will neutralize other molecules in accordance with their relative numbers of hydrogen ions or hydroxyl groups, rather than on a strict one-to-one basis.

Acids having more than one hydrogen ion are called "multi-basic". For example, sulfuric acid is a "dibasic" acid because one molecule of sulfuric acid could neutralize TWO molecules of a simple base. Carbonic acid, H_2CO_3, which gives soda pop its tart and tingling taste, is another example of a dibasic acid.

Multi-basic acids (or bases) do NOT have to necessarily always be completely neutralized. For example, if you use only HALF as much sodium hydroxide as required to react with a certain amount of carbonic acid, the reaction would be:

$NaOH + H_2CO_3$ ----- $H_2O + NaHCO_3$ (sodium BICARBONATE)

or if you neutralize a certain quantity of calcium hydroxide with only HALF the quantity of nitric acid, you would get:

$HNO_3 + Ca(OH)_2 \dashrightarrow H_2O + CaHNO_3$ (calcium acid nitrate)

So you can see that neutralization reactions can proceed in "steps", whereby only one-at-a-time of the available hydrogen ions or hydroxyl groups are neutralized, rather than all of them at once.

The familiar "Baking Soda" is sodium bicarbonate, an example of such a partially-neutralized salt.

Let us learn one other useful fact here. The driving force behind all neutralization reactions is the union of the hydrogen (or hydronium) ion with the hydroxyl groups to form water. And this reaction tends to GO TO COMPLETION for the very good reason that water is so poorly ionized itself that it removes itself from the scene of the reaction as fast as it is formed. Hence, such neutralization reactions TEND TO GO TO COMPLETION.

This is a general principle that the formation of a poorly-ionized reaction product is one of the ways we have of making chemical reactions go essentially in ONE DIRECTION ONLY.

In general, chemical reactions tend to go to a "steady state", called "chemical equilibrium", in which the reaction products are reacting backwards as fast as they are forwards. Such an equilibrium condition is of course actually highly "dynamic" because things are still happening. However, if you measure the actual amount of reactants and products, there is no further change, and the reaction appears to be standing still.

Chemical equilibrium can be thought of in terms of two large water-filled glass globes connected by a narrow channel. In the beginning, let us put 100 fish into only ONE of the globes. After awhile, some of them will find the narrow channel, and swim over into the other unoccupied globe. This situation will continue, fish going in BOTH directions occasionally, until finally BOTH globes will have about 50 fish apiece (equilibrium condition). Fish will continue swimming from one globe to the other, but due to the laws of chance, at any given moment, the count would still remain close to 50 fish in each of the globes. To all intents and purposes, nothing is happening; but like our chemical equilibrium, obviously the fish would continue to swim about in both directions, and in reality you would have a very "dynamic" situation.

So you see that the average chemical reaction wants to get to an equilibrium condition rather than go overwhelmingly to one direction or another. And you can see how important it can be to learn how to make reactions go essentially to "completion" in one direction. Later on, we will mention other ways of accomplishing this purpose.

Salts, in general, are always formed as products of a neutralization reaction. A salt is therefore a particular type of chemical compound, of which table salt is just one example.

Salts are always ionized in water solution. That is, they break down into ions, and can carry electrical current. The degree of ionization varies. Among other simple methods, it can be measured by the "lowering of the freezing point", or "raising of the boiling point" mentioned in earlier chapters.

We should mention here, for the sake of truth, that as far as we know the "degree of ionization" is a convenient myth. In reality, evidence shows that salts are already completely 100% "ionized" even in the solid state, and the water merely accomplishes a separation between ions. The fact that salts, acids, or bases DON'T behave in solution as if they were completely ionized is probably due to certain mutual interference factors. However, the "degree of ionization" is a useful tool, and one that is easy to visualize and use mathematically.

Based on this convenient way of looking at ionization, we can write reactions as follows:

$$NaCl \longleftrightarrow Na^+ + Cl^-$$

This indicates to us that in solution sodium chloride exists mostly as the individual "ions", rather than as molecules of sodium chloride.

The equation:

$$H_3PO_4 \longleftrightarrow 3\ H^+ + PO_4^{-3}$$

This indicates to us that phosphoric acid exists in solution mostly as molecules, rather than as hydrogen ions and phosphate ions.

The equation for water:

$$H_2O \longleftrightarrow H^+ + OH^-$$

tells us that water also prefers to remain as the molecule, rather than as hydrogen ions and hydroxyl groups.

Chemists can actually figure out the relative numbers of parts on both sides of the above equations, and thus give numerical values to the "degree of ionization". The above equations, by the way, are called "ionic reactions".

From the above equations, can you see now why pure water is NOT a very good conductor of electricity? Remember that ions in solution, being free to move about, and being electrically charged themselves, are the particles that can carry an electrical current.

When acids and bases are made to react quantitatively, for purposes of exact analysis, we call the process "titration". The process consists of slowly and carefully adding measured quantities of an acid to the base, or vice versa, until our indicator changes color. At that point, known as the "end-point", we know that we have added just enough to exactly neutralize each other.

For instance, if you worked in a plant which made sodium hydroxide (lye) (caustic soda) by electrolysis, you would want to keep tabs on the process. You would do this by taking a sample from your electrolytic tank at intervals, and "titrating" the sample against a known solution of some acid until your indicator tells you that the neutralization is complete. You could then figure out how much caustic soda was present in your sample, and how your process is doing.

FOOD FOR THOUGHT:

1. If a certain element is burned in air to give a gas, and the gas when dissolved in water forms an acid, is the element a metal or non-metal?

2. Explain why the harmful effect from swallowing hydrochloric acid must be from the hydrogen rather than from the chloride ion.

3. Do all acids contain hydrogen?

4. Methane, CH_4, contains hydrogen. Does this make it an acid?

5. Describe a simple experiment to tell whether an acid is strong or weak.

6. If a person gets some sulfuric acid spilled on his skin, why wouldn't it be best for him if you run away and look for a doctor?

7. Boric acid is frequently used as an eye wash. Is this a strong or weak acid?

8. Describe a simple experiment to tell whether or not a solution contains ions or not.

9. In pure neutral water, what could you say about the relative numbers of hydrogen ions and hydroxyl groups?

10. When sodium carbonate, Na_2CO_3, is dissolved in water, how many ions are formed from each molecule?

11. Could you think of at least one more way of making a chemical reaction proceed to completion other than the one mentioned?

12. When you dissolve an ionizable salt in water, what can you say about:

    a. The number of positive and negative charges in solution?

    b. The number of positive and negative ions in solutioN?

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 19--ELECTROCHEMISTRY

It has long been known that a flow of electrons along an electrical conductor (such as a metal wire) will produce an electric current. There are several ways of creating such an electron "flow". One of them is by means of chemical reactions.

As you know by now, ordinary chemical reactions involve the outermost electrons (those furthest away from the nucleus of the atom), and frequently involve the "transfer" of such electrons from one kind of atom to another (creating "ions").

Atoms from different elements do NOT necessarily have the same desire either to give up, or to take on, electrons. In fact, since the number and arrangement of electrons is different for each element, the tendency to want to take up more electrons or to give them off is also different for each element.

From this it follows that if we can put any two elements into electrical contact, one of the two will have a greater tendency to take on extra electrons, and the other will have a greater tendency to give them up. This difference in the behavior of their outer electrons may be quite large, or rather small. It depends on several factors, but partly on the number of electrons which already inhabit the outer orbits.

To take a simple example: the metal sodium has only one electron in its outermost orbit (or "shell"). It has a very large tendency to get rid of this one electron, thus becoming a sodium ion with a single positive charge. The non-metal chlorine has seven electrons in its outermost "shell". It has a strong tendency to ADD an extra electron to this "shell", thus becoming a chloride ion with a single negative charge. (Remember that all atoms are NEUTRAL to begin with.)

The net result of the above is that when atoms of the element sodium are placed in contact with atoms of the element chlorine these electrons are transferred as indicated, and an ionic compound sodium chloride is formed by the chemical combination of these two elements.

Supposing that instead of a metal and a non-metal, we were to take TWO METALS. One would still have a greater tendency than the other to gain or lose electrons. If we provide some way for this transfer to take place, we can measure this tendency by means of an electrical meter (galvanometer).

Since this transfer, or "flow", of electrons produces an electrical current, it can be made to do useful work also. This is the basis for the science of electrochemistry. This is the basis for the operation of the battery in your auto, your flashlight, and the source of power for many children's toys, and some large industrial equipment.

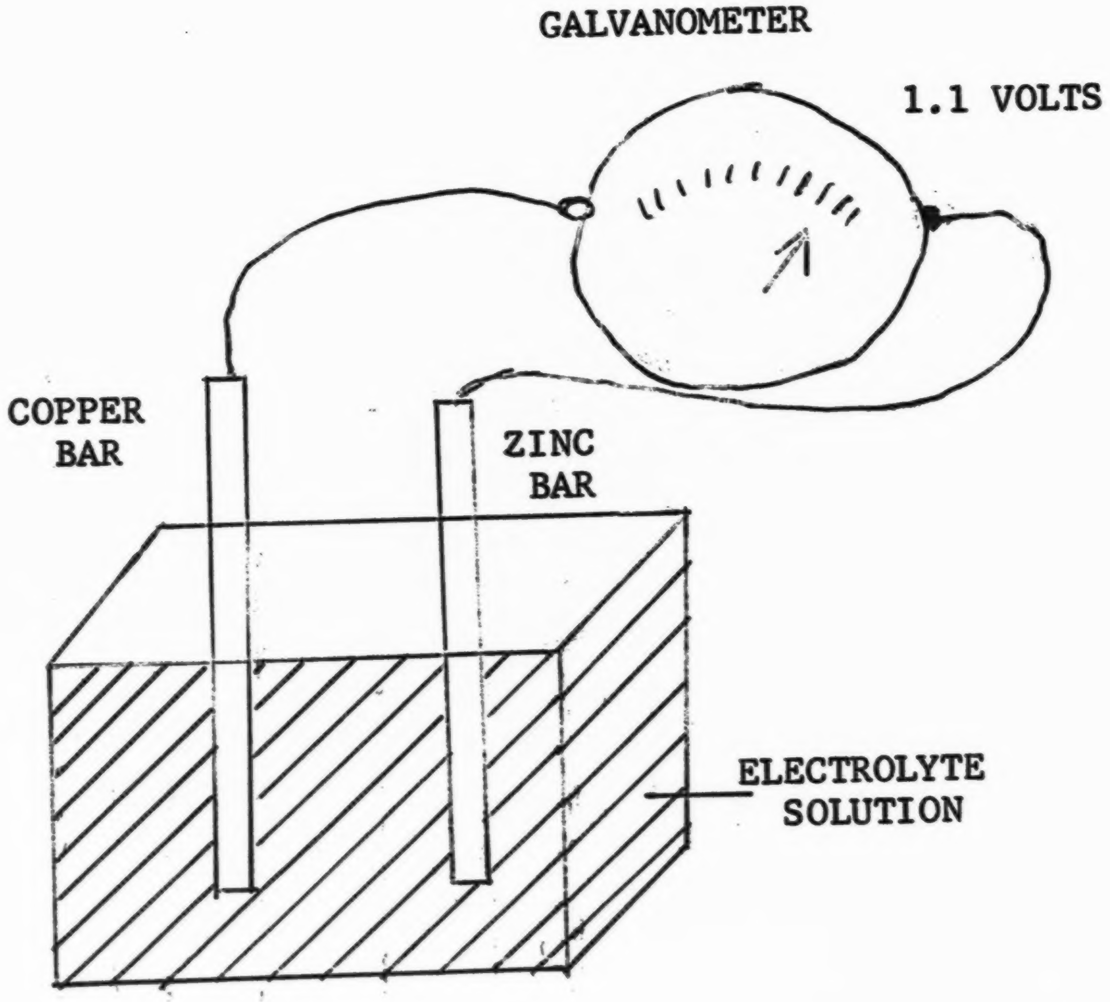
Take two pieces of different kinds of metal and connect one end of each to the terminals of a "galvanometer" (which is a simple meter device for measuring the passage of an electrical current). Lower the other ends into a beaker containing a solution of electrolyte. The galvanometer needle will swing to one side, showing that an electrical current is being generated (electrons are flowing through the wire).

If we allow the process to continue for awhile and then carefully weigh our pieces of metal, we would find that one has GAINED WEIGHT, while the other has LOST WEIGHT. In fact, the gain or loss in weight of the metals would be directly proportional to the amount of electricity produced. We could also show that heat energy is produced because a thermometer would show a slight change in temperature.

From the above we can see that the production of electricity is connected with a chemical reaction. Conversely, chemical reactions can produce electricity as one of the forms of energy released. Like every other aspect of chemistry, this energy is quantitative with respect to the reaction which produces it.

Pieces of metal immersed in a current-carrying solution (solution containing an electrolyte) are called "electrodes". If the two pieces of metal are the same element, NO CURRENT will flow because there will be no tendency for the electrons to go from either one to the other. But if the two metals are of DIFFERENT ELEMENTS, there WILL be such a tendency, and one electrode will become the POSITIVE electrode and the other will become the NEGATIVE electrode for that particular combination of metals.

One of the earliest types of battery was the "Galvanic Cell", made by immersing a strip of zinc and a strip of copper in an electrolytic solution. This was a battery which could produce a flow of electrical current and gave a voltage reading of about 1.10 volts. Other pairs of unlike metals can be used, the choice depending upon many factors such as: cost of the metal, voltage required, ease of obtaining the metal, etc. Most of the factors are economic ones.



Since even the highest voltage differences amount to only a few volts, very high voltages must be obtained by wiring cells "in series". Thus, six Galvanic Cells wired in series will produce a final total voltage of 6 X 1.10 volts, or 6.60 volts total.

In most cases today electrical generators can produce power more economically than from chemical batteries. However, batteries are portable, and where portability is a necessary factor, batteries can be used.

It is possible to compare each metal with all the others with respect to their relative voltages. In practice this is done by pairing them up with an electrode using hydrogen gas which in many ways acts like a metal itself. (For example, look at its valence.) If we do this, we arrive at a table of voltage values called the ELECTROMOTIVE SERIES.

THE ELECTROMOTIVE SERIES: (or EMF Series)

(A partial list is given for the more common elements)

VOLTS	ELEMENTARY ION
+ 3.00	Li^+
+ 2.92	K^+
+ 2.90	Ba^{++}
+ 2.71	Na^+
+ 2.34	Mg^{++}
+ 1.67	Al^{+++}
+ 0.76	Zn^{++}
+ 0.25	Ni^{++}
+ 0.14	Sn^{++}
+ 0.13	Pb^{++}
00.00	H^+ (reference element)
- 0.34	Cu^{++}
- 0.80	Ag^+
- 0.85	Hg^{++}
- 1.42	Au^{+++}

(A similar table can be made for the non-metals also.)

Care must be used in interpreting the above Series to pay proper attention to the value of the plus or minus sign. The actual DIFFERENCE IN VOLTAGE for any metal pair is what counts. Thus if one metal has a voltage of MINUS ONE, and the other one of PLUS THREE, the voltage obtained by using this pair in a battery would be FOUR VOLTS.

To take actual examples from the above Series: a battery made using Lithium and Nickel electrodes would give a voltage of 2.75 volts. Lead and Copper electrodes would give 0.47 volts.

If we keep in mind that the electrical power from batteries comes from chemical reactions and is subject to the same influences as other chemical reactions, this helps in understanding them better. On a very cold day in winter your auto battery will not be able to provide electrical power at its usual high capacity because the lower temperature slows down the chemical reactions involved.

The "dry cell" which powers your flashlight has one carbon and one zinc electrode and puts out about 1.5 volts. The electrodes operate in a "paste" electrolyte rather than a liquid which contains zinc chloride. Continuous operation tends to build up undesirable "side reactions" which slow down the main chemical reaction. Letting the battery "rest" for awhile gives these "side reactions" a chance to stop, and results in the light becoming stronger again.

Modern "fuel cells" can convert the combining of oxygen and hydrogen gases directly to electrical energy.

The present auto battery is, as you know, rechargeable. When the reacting chemicals have been used up, the flow of electrical energy stops, and the battery is "dead". By putting electricity INTO the battery at the proper voltage and flowing in the proper direction, the chemical reactions which produced electricity are reversed, and the original chemical reactants are regenerated. After the "charging" process, the battery can be used again to produce electricity. In your auto this is a continuous process since the generator recharges the battery while you drive.

If chemical reaction can produce electrical energy, the reverse is true also. We can produce chemical reactions by putting in electrical energy. One of the most useful applications of this is in the Electroplating industry. Another very useful application is for producing chemical elements from their compounds.

In many cases it is desirable to put a thin "coating" of one metal on another. For example, cheap copper or brass jewelry can be covered with a thin coating of gold or silver to give it a more attractive appearance or catch the unwary buyer. Tableware may be plated with silver. The coating might be for protective purposes, rather than decorative. An iron auto bumper is coated with chrome metal because chrome will not rust whereas iron will. The list of possible applications is endless. Such coatings are called "plating", and are made by immersing the article in a solution of the plating metal, and passing electricity through the system in the proper direction.

A thin plating of tin on iron or steel cans makes them suitable for storing food products over long periods of time because of the almost total insolubility of tin salts.

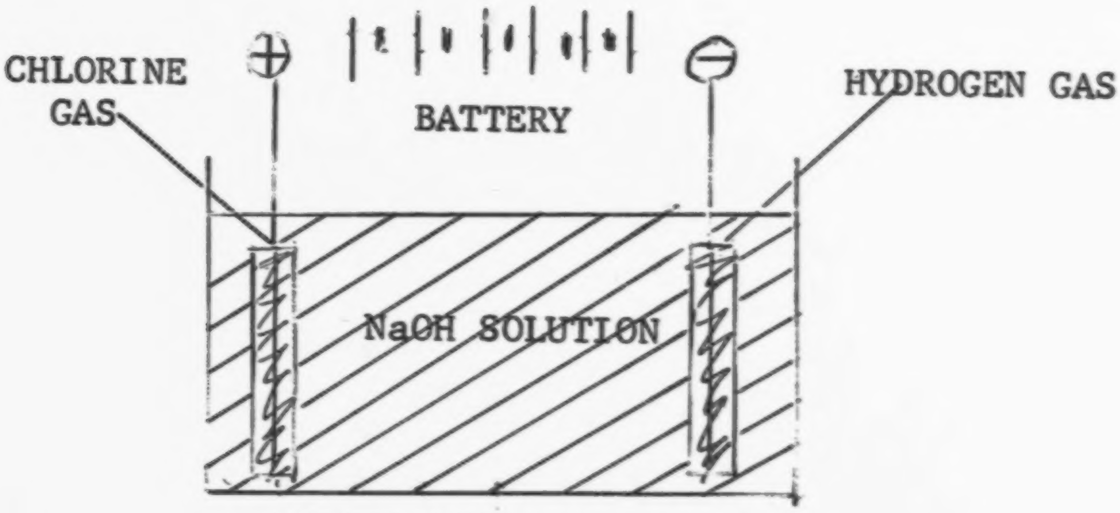
By certain techniques electroplating can be extended even to ceramics. Gold can be applied to glass, for example.

The recent coating of plastic articles with metal is done by a process called "vacuum spattering", and strictly speaking is not electroplating even though the results are similar.

Plated coatings are usually VERY thin, only a few thousandths of an inch or less. If the plated metal is rather soft, it can be scratched easily, or will wear down very soon. Plated jewelry will not last long for this reason.

The second application of electricity, to produce elements from their compounds, is the basis of tremendous plants and production running into millions of tons per year.

The two elements Chlorine and Hydrogen can be produced by this method by passing electrical current through a solution of sodium chloride:

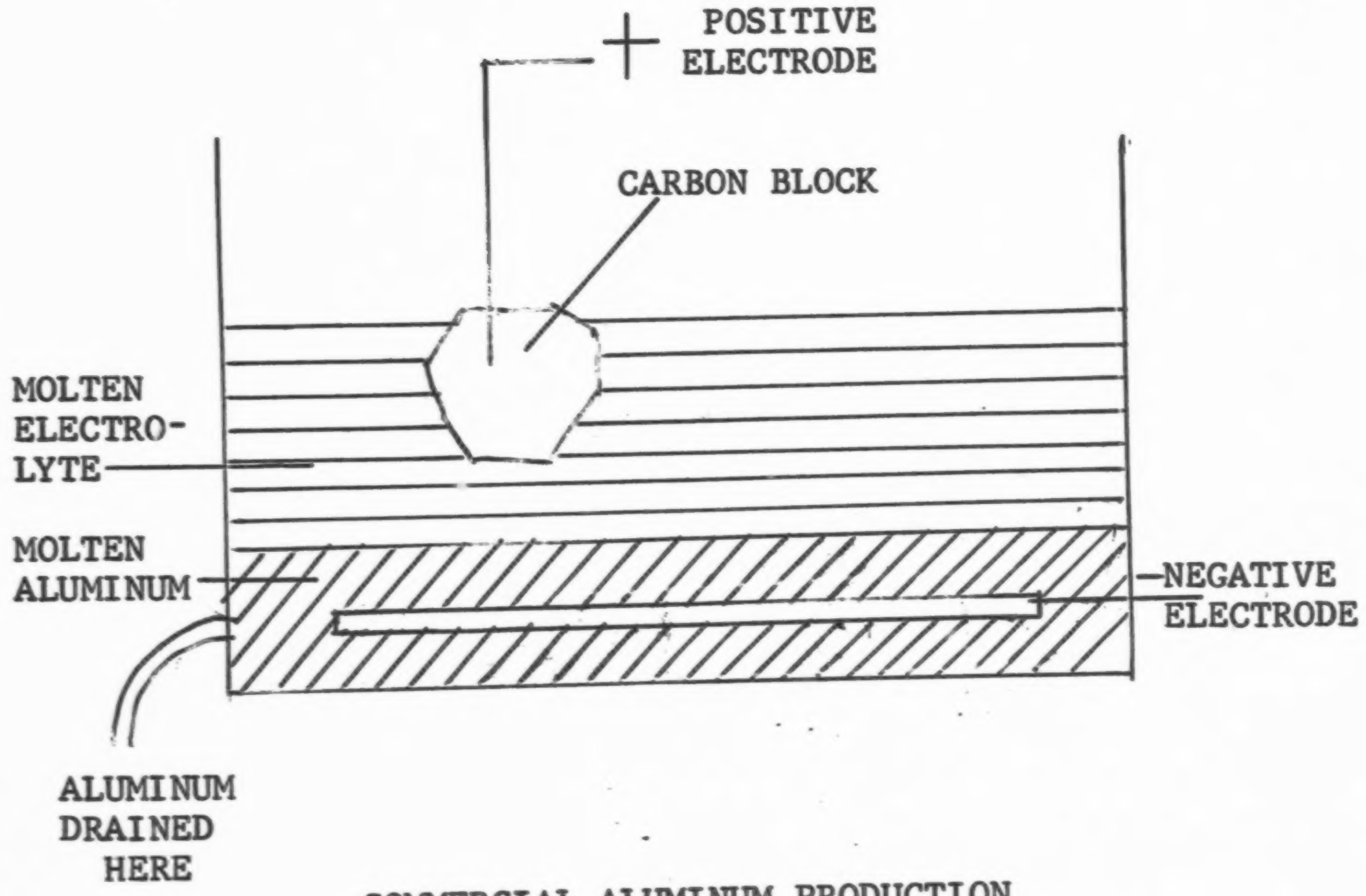


ELECTROLYSIS OF BRINE

Chloride ions are attracted to the positive pole of the cell, give up their extra electrons, and the element is given off as chlorine gas. At the negative pole the reaction is a little more complicated. Sodium ions migrate there, but since water also contains some hydrogen ions, and since the EMF Series shows that hydrogen can gain electrons easier than sodium atoms, this is what takes place. Accordingly, hydrogen gas is released at the negative electrode.

One of the outstanding examples of producing a metal by electrolysis is that of aluminum. Once a rare element selling at $100 a pound, the discovery of an electrolytic method made the metal available very cheaply. This process is carried out at high temperature because the aluminum oxide which is the source of aluminum must be dissolved in molten "cryolite" (Na_3AlF_6).

The cell for producing aluminum looks essentially as follows:


+ POSITIVE ELECTRODE
CARBON BLOCK
MOLTEN ELECTRO-LYTE
MOLTEN ALUMINUM
NEGATIVE ELECTRODE
ALUMINUM DRAINED HERE

COMMERCIAL ALUMINUM PRODUCTION

Because plating and other chemical/electrical reactions are quantitative, another use for such reactions is in analytical chemistry to determine HOW MUCH of an element is present in an unknown sample. For instance, a weighed sample of copper ore can be dissolved in acid, and the copper plated out (under properly controlled conditions) on a weighed electrode. These are simple and direct methods, but in many cases interfering chemicals may have to be removed first by other procedures. Copper and lead are frequently determined in ores by this method.

FOOD FOR THOUGHT:

1. What would be the chief objection to using Gold as one element in a chemical cell? Sodium metal? Hydrogen gas?

2. What voltages could you get from a cell with the following pairs of metals:

_____a) Sodium / Potassium? _____ c) Zinc / Silver?

_____b) Mercury / Copper? _____ d) Gold / Magnesium?

3. The newer cells for transistorized radios use mercury and zinc. What voltage would you expect from this combination of metals? Is the high cost of such batteries justified by the ingredients?

4. In older auto batteries the fluid level requires filling. Since the electrolyte used in such batteries is sulfuric acid and water, what do you have to add to bring the fluid level back to normal? Why?

5. Why would pure metals exposed to weather be more likely to resist corrosion than the same metals having impurities?

6. When you touch a filled tooth with a piece of metal, what happens?

7. Is a "dry" cell really dry?

8. If you spill acid from an auto battery on your skin, what should you do?

9. If application of an electric current could plate an object, would the object be "de-plated" if you reversed the current?

10. Does plating require direct current or alternating current? Why?

11. Would a battery using sodium metal be very practical? Why not?

12. If you had a storage battery that needed charging, but did not know which was the positive pole and which the negative pole, what simple experiment could you perform to solve this problem?

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 20--METALS AND NON-METALS, ALLOYS

You have already acquired quite a bit of knowledge regarding the differences between elements which are "metals" and those which are "non-metals" so it is time to gather up the loose ends and take a good look at these two common classes of materials.

Metals and non-metals do have some sharp differences in behavior in some ways, and yet in many other ways there is a very gradual transition from one to the other--so gradual in fact that in some cases we find elements able to behave as both. So don't expect a clean-cut dividing line in every respect. You won't find it.

1. PHYSICAL PROPERTIES:

Metals have a "metallic lustre".
Metals conduct heat quite well.
Metals conduct electricity.
Metals are "malleable" (can be pounded thin).
Metals are "ductile" (can be drawn into thin wires).
Most metals have a silvery color, but a few are bluish, grey, gold colored, or copper colored.

Density of metals covers a wide range:
Lithium is lighter than water, but gold has a density of 19.3.
Metals are opaque--they don't let light pass through them.
Metals are all solids (except for mercury, which is a liquid at ordinary temperature).

Non-metals have a variety of surface appearances.
Non-metals have a variety of colors.
Non-metals don't conduct heat very well.
Non-metals don't conduct electricity.
Non-metals, if solids, are frequently brittle.
Some non-metals are gases, some liquids, some solids.
Some non-metals are transparent.

Looking at the above you can see that there are rather large differences. Thus, physical properties are a good way to tell the difference between metallic or non-metallic elements.

2. CHEMICAL PROPERTIES:

Metals form oxides which react with water to give bases.
Metals are usually "electro-positive"--they want to lose electrons.
Metals usually have a positive valence.

Non-metals form oxides which react with water to give acids.
Non-metals are usually electro-negative--they want to gain electrons.
Non-metals usually have a negative valence.

The chemical activity of both metals or non-metals varies with the element itself over a wide range.

Some of the metals (such as sodium potassium, lithium) are so reactive that they combine violently with water. Exposed to the air they soon form oxides. Others, of course, will last for years without change. Again, some of the non-metals show tremendous chemical activity. Fluorine cannot be held in glass containers because it reacts with the glass rapidly.

In between the two easy to distinguish groups exist an in-between group of elements which sometimes behaves (chemically) as a metal, sometimes as a non-metal. These are called the "transition" elements. The elements manganese and chromium, undoubtedly metals in many ways, are still "transition" elements. Besides acting as a typical metal in such compounds as manganese dioxide, chromium sulfide, etc. they also form compounds such as potassium permanganate, $KMnO_4$, and sodium chromate, Na_2CrO_4, in which these elements act chemically more like a non-metal (look at sulfur in K_2SO_4). Antimony and arsenic, both good poisons and both found freely in many natural ores, are two more elements which can act in either way.

So the thing to remember is that certain elements are quite strong and unique in their behavior as metals. Certain other elements are strong and unique in behaving as non-metals; and a rather large group in between the above (the transition elements) can and do behave either way, depending upon other external influences.

ALLOYS: Typical metals (and some of the transition elements) can be mixed together in the molten state. Sometimes there is a limit to the mixture, and one element can contain only a certain percentage of another. Sometimes there is no limit, and the two (or three, or even more) are completely "miscible" over the entire percentage range. Such metallic mixtures are called by a special name--"alloys".

Alloys play a large part in our everyday life because by the proper blending of metals we can impart properties to fit different purposes. We can make iron tougher or softer, more malleable or less, more brittle or less brittle, more resistant to corrosion or less, stronger or weaker, denser or lighter. Such a blend of aluminum and magnesium is today making airplanes lighter while reducing the fire hazards which would come from using magnesium metal by itself. We can make wire more capable of carrying electricity, or capable of carrying it with less heat loss. We can make steel plate so tough that an armored shell will not go through it.

Steel itself is an alloy. In this case the most important alloying ingredient isn't even a metal; it is a carbon. Traces of other elements are needed also, but the product steel is much better than iron for many uses.

Not all metals will form alloys. In some cases they belong to "crystal systems" which are too unlike, and thus are not compatible with each other. Important alloys are being made which contain only a few tenths of a percent of alloying elements while in other cases the alloying elements may each be present in high proportion.

In some cases, besides forming just mechanical mixtures metals will form also definite compounds with each other. Frequently, alloys will include such metallic compounds, PLUS mechanical mixtures. The field is very complex, and is studied especially in what is called "Metallurgical Chemistry". Much of our modern progress in space and in other directions of human endeavor has resulted from the work of the metallurgist in producing special alloys, and much work remains to be done in this field.

Alloys have one peculiar property. Remember that you learned that the physical properties of mixtures lie between the physical properties of both ingredients? For example, the density of a mixture of sand and water will be somewhere between the density of sand and the density of water. In general this is true of alloys also. However, for some particular percentage composition for each metal pair in an alloy, the melting point will be LOWER than that for either metal.

As an example of this, the melting point of Cadmium is 321° C, and the melting point of Zinc is 419° C. If we make a series of cadmium-zinc alloys, most of their melting points will lie between the two above values. BUT, at a mixture of 82% Cadmium and 18% Zinc, the melting point will drop down to about 260° C (below either one). This is true of ALL alloys. This lowest melting point of an alloy is called the EUTECTIC POINT, and the composition at that point is called the EUTECTIC COMPOSITION.

Using this device, we can make metal mixtures (alloys) which melt BELOW THE BOILING POINT OF WATER. Some of these alloys are used in automatic sprinkler systems where an undetected fire melts an alloy plug in the water line, and allows water to escape, thus putting out the fire. Conversely, an alloy is usually harder than either of the metals composing it.

It's a big world, isn't it; and there are lots of interesting things in it.

Amalgam: Mercury metal can form alloys with some of the other metals, especially gold, silver, and copper. Such alloys containing mercury are called "amalgams". The recovery of elementary gold and silver in many mining operations is based in part on the use of mercury to catch and hold fine particles of precious metals as an amalgam. Since mercury is volatile (the fumes being very POISONOUS), it is easy to separate from other metals in an amalgam by distillation.

Amalgams have another very prominent use. When the dentist fills your teeth with a metallic-looking material, this is another mercury alloy with special properties to make it harden very quickly.

FOOD FOR THOUGHT:

1. What are the "noble" metals, and why are they called that?

2. In nature most metals are found as the oxide, sulfide, or the carbonate. Why this way rather than the free metal itself?

3. Where do most of our metals come from?

4. Could you carry a piece of sodium metal around in your hand? Why not?

5. Could you carry a piece of phosphorous around in your hand? Why not?

6. If the element Fluorine is so active it will even react with glass, do you suppose it would harm you to breathe it? Why?

7. Why is the element Iodine used on open cuts?

8. How would you make an alloy of silver and copper in the laboratory? What would determine the color of the alloy? Would the alloy be harder or softer than either metal alone? Do you suppose the alloy would be a good conductor of electricity?

9. Could you make an alloy of silver and copper which would have a melting point BELOW that of either silver or copper alone?

10. Can you think of any other uses for very low melting alloys?

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

4

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 21--RADIATION

You learned in a recent chapter that one of the ways that heat energy could be transferred was by means of radiation. In the case of heat energy we call this "infrared" because it is beyond the red color of visible light.

The transfer of heat energy by radiation is an example of part of the so-called "electromagnetic spectrum". This spectrum is a continuous range of radiation, or radiated energy, running in our present state of knowledge from radio waves to gamma rays.

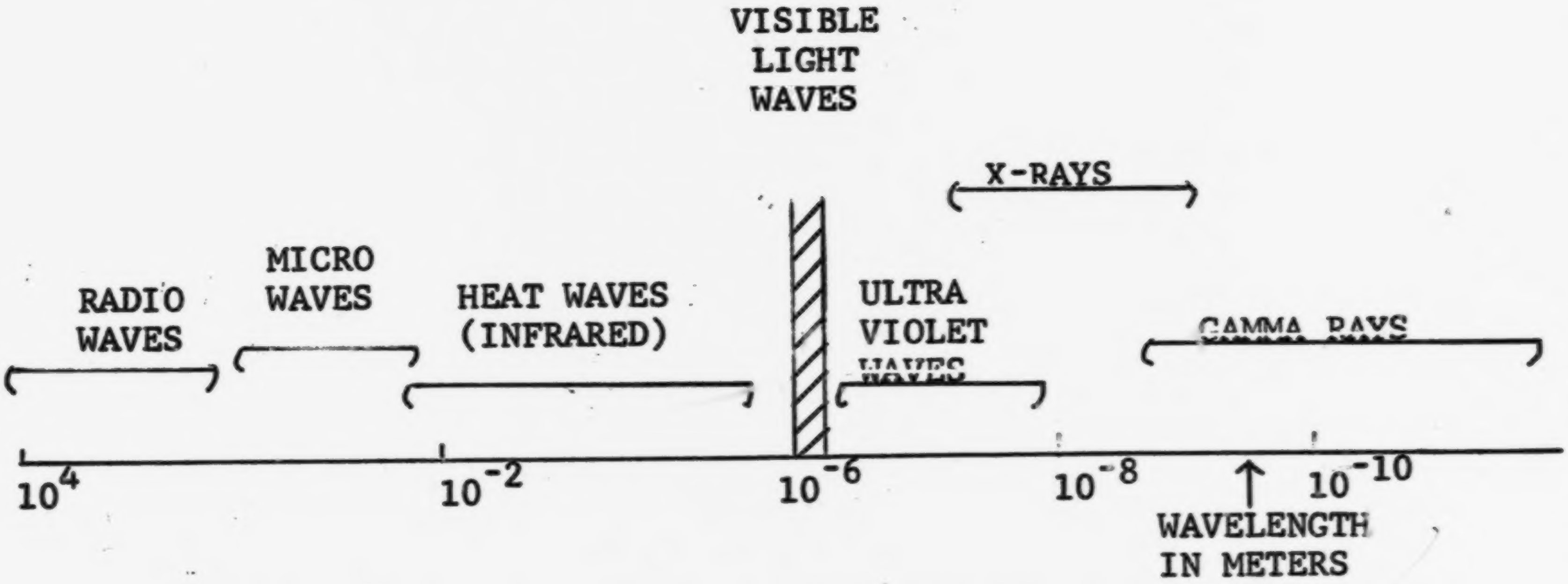
If you fasten a rope to a post and shake the loose end with an up-and-down motion, you will be creating a wave motion in the rope. The motion you impart to the rope will to a large extent determine the shape and spacing of the wave disturbance. The distance from one wave "crest" to the next would be the wavelength.

In the electromagnetic spectrum, the main difference between one type of radiation and another is the wavelength. Thus radio waves have a relatively long wavelength, visible light waves much shorter, and gamma rays much shorter still. The difference in wavelengths accounts for a tremendous difference in properties also. A radio wave can carry the human voice, or sounds of a great orchestra, for hundreds of miles. A blue dress looks different from a red dress because of the different wavelengths reflected from the material. A gamma ray can penetrate metal, but will be stopped within a few inches or less, and is invisible.

We are able to see because our eyes can detect a small portion of this spectrum, but all the varied beauty of the world is comprised in this small group of visible wavelengths.

The entire electromagnetic spectrum range has the same physical nature and is propagated with the same speed, that is the speed of light at 3×10^8 meters per second (300,000,000 meters per second). Even at this speed it takes about eight minutes for the sun's light to reach earth, and the same speed for the sun's heat to arrive here by radiation, therefore.

The Electromagnetic Spectrum:



Notice that some of the regions overlap. The names of different spectral regions are somewhat arbitrary, and refer to their use or origin.

Very briefly, electromagnetic energy is radiated by decelerating a point electrical charge. Since ions, radicals and electrons are small charged bodies, accelerating or decelerating them will generate electromagnetic radiation.

Of interest particularly to students of chemistry is the fact that if we take some atoms of a metal, for example, and heat them strongly in a flame, the heat energy imparted to the atom causes some of the outer electrons to become "excited", and they are forced into orbits further away from the nucleus of the atom. Some of these electrons drop back into their former orbits, closer to the nucleus; and when this happens, the difference in energy is "radiated" as visible light. Since the energy comes in "steps", depending upon the jump of the electron from one orbit to another, the light it releases will also come in "steps" of only certain wavelengths, which in turn will correspond to certain colors.

By passing such light through a prism, or through closely ruled lines on a glass plate (called an optical "grating"), the light is broken down into its individual wavelengths and the exact orbital paths which caused the particular wavelengths to be given off can be calculated.

By this means, much information regarding the structure of atoms, molecules, and matter in general has been obtained. The particular instrument used for this purpose is called a "spectroscope". Since each element has different atoms, they will behave differently under the influence of external exciting influences, and the light they give off will be distinctive. In other words, the light given off by sodium ions will have a different pattern and arrangement of spectral lines from the light given off by any other element. The spectrum for each element is as distinctive as a fingerprint. Thus, the spectroscope can be used to determine what kinds of elements are present in mixtures.

By this means, the presence of a rare gas--Helium--was discovered ON THE SUN before it was ever found on earth. By this same means, a prospector can run a single sample and identify perhaps a dozen elements present in that sample. Also in this way we can find out something about the chemical reactions proceeding on our sun, and in distant stars since their light comes to us across empty space.

Historically, the study of radiation started with an inquiry into certain natural ores (or radium and uranium) which were found to give off some kind of invisible "ray". We know now that these invisible rays were themselves rather complex. For example, radium gives off three separate kinds of rays: alpha rays, beta rays, and gamma rays. And each of these originates in a different way and has different properties. Actually, of these only the gamma rays are part of the electromagnetic radiation spectra. (The other two are streams of moving particles.)

When a fast-moving stream of electrons (moving in a vacuum) is suddenly stopped by hitting a "target" material, another kind of electromagnetic ray is given off. For want of a better term, these were originally called "X-Rays", and the name has stayed with them.

X-Rays and Gamma Rays are fairly similar in their properties. Both will penetrate matter. The depth of penetration and the type of material penetrated depends upon the wavelength of the ray involved. Both are quite dangerous to flesh. Even very short exposures can cause burns which take a long time to heal. But since X-Rays are man-made, we can control them better. We have learned, therefore, to use X-Rays in taking photographs of broken bones or damaged organs inside living bodies. Another recent use is the treatment of diseased tissues, such as cancer.

In the treatment of cancer and similar diseases, the use of X-Rays or natural radio-active material is based on one principle: that the rays damage diseased tissue FASTER than normal tissue. Thus, properly measured dosages can kill off cancerous tissue, and leave normal flseh relatively unharmed.

X-Rays and the rays from natural or man-made radioactive materials are not playthings for the untrained.

Even a brief exposure of one second to strong X-Rays can cause a burn which may not heal for years, and the carrying of a small piece of radioactive mineral has cost dearly for some careless prospectors. When used to benefit mankind, such natural forces have to be understood and handled with great caution.

In recent years, man has learned to create radioactive elements which did not exist before. These elements in turn give off a variety of "rays" from which we can learn a lot about our universe. One such usage for radioactive "isotopes" is in the study of chemical reactions. By using the isotope we can put a "label" on certain elements in the reaction, and follow them through different stages of the reaction.

Some of these man-made radioactive isotopes emit rays which are quite strong and harmful. However, others are weak, mild, or have a very short "life". The latter type can be used directly in the body to study chemical reactions and find out what happens to certain kinds of compounds or elements in the body.

Would you be astonished to find out that you are not the same person you were yesterday? By labelling body cells and food with certain radioactive isotopes, it has been found that as high as 50% of your body's fat deposits are changed every 24 hours, and that in about seven months you will have a completely NEW body, every atom in it having been replaced.

Since the stopping (negative acceleration) of charged particles causes the emission of radiation, let us look at a television set. The picture tube is a large vacuum tube in which millions of fast moving electrons are accelerated rapidly, and then hit a phosphorescent chemical on the inside of the tube. Due to the current and voltage changes which determine the path of the electrons, a picture is formed. But the same situation can, and does, cause the emission of X-Rays. In a properly made set this factor has been taken into account and minimized.

Some of the recent color television sets have had trouble with the emission of X-Rays in possibly harmful amounts. Think twice before you sit too close to your television set....

The earth has a radiation zone, or "belt" which could be quite hazardous to astronauts. Part of this radiation originates far from the earth (the sun, for example); part of it may come from reactions in earth's upper atmosphere. In any case, there are probably other types of radiation which have not been discovered yet, and which, like X-Rays and radio waves may have quite an effect on our future.

FOOD FOR THOUGHT:

1. We can understand a wave motion in water, or in a piece of rope. If light is a wave disturbance like this, WHAT kind of medium is being disturbed? Discuss this.

2. You have heard probably that dogs are able to hear sounds too high in pitch (shorter wavelengths) than the human ear can detect. Do you suppose that other animals might be able to detect colors which we could not see?

3. If it takes eight minutes for the light from the sun to reach the earth, when you look at the sun with a telescope, are you seeing events the moment they occur, or eight minutes after they occur?

4. If the nearest star were 1,000 light-years away from the earth and you could build a telescope powerful enough to show events occurring on this star, would the events be up-to-date?

5. If some intelligent force on the sun gave out a radio signal, how long would it take to get to the earth?

6. If you were faced with the problem of trying to measure the speed of light, HOW might you go about it?

7. Instead of looking into a spectroscope with your eye and seeing the pattern of colored lines, do you suppose that you could photograph the lines as a permanent record?

8. Explain why two elements could NOT give identical spectra.

9. If you were a dental technician taking frequent X-Ray photos of patients' teeth, do you think you would have to take any precautions for yourself? If so, what?

10. In the treatment of cancer by X-Rays, why not expose the diseased flesh continuously until the disease is cured?

11. If you were a detective, could you think of any application of radioactive isotopes?

12. If television sets might put out harmful X-Rays, why not simply put a lead metal shield on the inside of the tube between the source of electrons and the picture tube?

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 22--ORES, MINERALS, AND MINING

We live, in New Mexico, in a highly-mineralized portion of the earth's crust. A mineral has been defined as any inorganic substance of definite composition. Minerals thus can be either metallic or non-metallic in nature. There are many thousands of minerals found in nature. Sulfur and water are examples of minerals which are important to us, but are non-metallic. In our area, lead sulfide and zinc sulfide are important metallic minerals.

An ore is a special class of a mineral. It is a mineral which can be used as a source of some useful substance. To be an ore, the mineral would have to be fairly abundant, and permit the recovery of the useful substance fairly easily. In this area, lead sulfide is an ore from which we make the metal lead. Malachite and azurite, both copper minerals, are local ores from which we obtain copper metal.

Colorful agates, found near Deming and Silver City, are also useful minerals. They are bought and sold to be cut and polished into various kinds of "rock jewelry", or gems.

Gravel, sand, limestone and other types of similar materials are used extensively in buildings or roads, and form part of our mineral wealth.

As mentioned elsewhere, minerals are a "one-source" crop. They cannot be replaced. For this reason they should be used wisely. In the next few years, the replacement of needed metals with plastics, ceramics, or other similar materials will be a necessary job for the chemist and engineer.

The recovery of ores involves the process called "mining", and mining may run from one man with a pick and shovel to a multi-million dollar operation involving thousands of workers. Mining is a very romantic field, and a very speculative one. A few miners have found riches, but many more had had little more than callouses and heartaches to show for their labors.

When an ore is found in sufficient quantity to justify a mining operation, the next step is to convert it to the useful substance (such as a metal). To do this, first it is necessary to "upgrade" the quality of the ore by some means of sorting--picking out the highest quality pieces and throwing away the rest. This can be done by hand, by magnetic or mechanical devices, or even by a "washing" process. The old gold prospector, rotating his gold pan to get rid of sand while leaving the gold particles behind, was making use of a combination of mechanical actions, including centrifugation.

On a larger scale operation, upgrading the ore is usually done in a "mill" where sorting, crushing, "jigging", "flotation", and other processes are carried out.

After the ore is upgraded, or "concentrated" to a fairly high content of metal or useful substance, the next step is to separate the metal (or other useful substance) in rather pure form. The process of separating the metal from the ore is called "metallurgy".

Some metals, such as gold or silver, may be found in nature as the elementary metal itself (uncombined). In such cases, recovery involves purely mechanical methods of operation, or sometimes a combination of mechanical and chemical methods.

Most of our useful metals, however, are too chemically active to be found as the metal itself, and are found in combination with other elements. Most metals, for example, are found in nature either as the oxide or the sulfide. The chemical process involved in recovering the pure metal thus depends upon whether we are dealing with an oxide ore or a sulfide ore. If the ore is an oxide, it is chemically "reduced" to produce the metal. If the ore is a sulfide, the first step might be to "roast" the ore in air, which burns off the sulfur as sulfur dioxide.

The extremely active metals (such as sodium, magnesium, etc.), as you have seen in the chapter on Electrolysis, are not handled in the above manner, but require special treatment and methods.

The extremely active metals (so-called "alkali" or "alkaline earth" metals) are capable of losing electrons fairly easily. In fact, in many cases just heating the metal or the salt of the metal in a flame will impart enough kinetic energy so that some of the outermost electrons are either displaced or thrown off completely from the atom. When they reach the cooler zones of the flame, such ions recapture electrons. Since it took energy to throw off the electron in the first place, energy must be GIVEN OFF when it recaptures the electron. This energy is emitted in the form of LIGHT RADIATION.

Since the atoms of every element are different, the light radiation emitted in the above process is also different. The eye sees this difference as a difference in COLOR. This is the reason that different minerals or metallic salts can impart different colors to a flame, and this is the basis of the so-called "flame test" for metals.

With the spectroscope (already mentioned) we can go much further than the eye and break down the colors of light into individual wavelengths which can be measured. When we do this, we find that each element has a characteristic "spectrum" which is as distinctive as a fingerprint.

The lone prospector, with some training and experience, can distinguish between many minerals by means of his candle, blowpipe, and the flame test. The discovery of Borax in Death Valley, California is a dramatic tale of the lone prospector and his burro founding a vast industry on the basis of the flame test for boron.

In the future this country and the world will uncover new methods of recovering presently rare metals and compounds. The space age is already making demands upon the chemist and engineer for materials which were laboratory curiosities only ten years ago, and will be commonplace tomorrow.

In your laboratory sessions, you will learn to identify some of the ore minerals common to the southwest, and in addition make some flame tests for metals. Your experience might lead you to discover an important orebody, but in any case it will enrich your life and give you a greater understanding of your environment.

FOOD FOR THOUGHT:

1. Why can we expect to find gold or silver as metals in nature, but not iron or calcium metal?

2. Going back to your Electromotive Series values, why do the very active metals (such as sodium) require special methods of manufacture?

3. What are some of the conditions required for a mineral to be an ore?

4. Suppose you learn to identify lead sulfide (galena). If you found a very large piece of this on a hillside in rough country ten miles from the nearest road, what should you do about it?

5. From your supplementary reading, what are some of the uses for:

a) silver
b) copper
c) lead
d) zinc
e) titanium
f) manganese
g) gold
h) nickel

6. Many of the so-called "heavy metals", like lead, are "accumulative poisons" to the human body. If you worked in a factory which reprocessed old automotive batteries, what kind of precautions could you take to prevent harm from lead poisoning?

7. Most gold processing plants, or mills, were located in a series of steps on the side of a hill. Why was this done?

8. One of the chemical methods for recovering small amounts of precious metals involves using cyanide solutions (despite the fact that cyanide is EXTREMELY POISONOUS). What special chemical property of cyanide makes it useful for this purpose?

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 23--CHEMISTRY IN AGRICULTURE

Modern chemistry has played a tremendous part in the growth of modern agriculture. The understanding of soil chemistry, plant chemistry, and the chemistry of unfriendly insects have each contributed greatly to making the earth bear greater yields of food materials, or materials useful for other purposes. In turn, food materials themselves have been broken down by modern chemistry into a greater variety of substances for human consumption, for household, or for industrial purposes.

The changes brought by modern chemistry are not always for the better. They sometimes meet a sheer necessity. But in this changing world in which man is beginning to see the earth as a "space ship" of rather limited capacity, everything will eventually have to be turned to man's advantage.

SOIL: The soil which covers so much of the earth's surface is composed of both inorganic mineral materials, and organic matter (matter containing carbon, which is so large a class that it is studied all by itself). All living things on our planet are based on carbon chemistry, so of course even dead animals and plants still come under the heading of "organic" materials.

Soil, therefore, contains mineral particles which are the products of weathering and disintegrative processes of rocks. It also contains living things of both plant and animal nature, and the products of their death and decay. A cubic foot of soil contains millions of small organisms, including algae, fungi, bacteria, worms, and insects, etc. Many of the living organisms play a large part in "soil chemistry" by converting inorganic elements needed by plant life into forms which the plants can use.

The most finely divided particles of soil, called clay, are responsible for holding much of the mineral matter and inorganic metal ions in the surface soil so that it does not get washed deep down into the earth and lost to any useful purpose. Clay is able to do this because it is in "colloidal" form as very fine particles. These fine particles (which usually carry an electrical charge) can hold metallic ions.

Plants require certain inorganic non-metallic and metallic elements for their successful growth. The most important elements are: Nitrogen, Phosphorus, Potassium, and Calcium. However, small amounts of other elemtns are also necessary. These are: magnesium, iron, sulfur, zinc, copper, boron, manganese, molybdenum, and chlorine. Since only small amounts of these latter elements are needed, they are called "trace" elements.

Since successive plant crops can take the elements they need out of the soil, it becomes necessary eventually to replace some of them. The first four elements, needed in larger amounts, are replaced by the "fertilizers" used as a routine process by the modern farmer. But in localized areas, the soil may suffer from a deficiency of one or more of the trace elements which then have to be added in small amounts.

Soil can suffer also due to an excessive condition of acidity or alkalinity which can be neutralized by the addition of cheap bases or acids to correct this condition.

The elements needed for plant growth must be present in a form that the plant can use. What counts is, therefore, not the total amount of needed elements, but the "available" amount. Fertilizers are bought and sold on this basis.

Quite a few compounds can supply nitrogen to the soil in a useful form. Years ago much of the demand was met by imports from Chile where huge deposits of guano were mined. In recent years, however, the nitrogen comes from the air, is converted to synthetic nitric acid and neutralized with sodium hydroxide to make the fertilizer sodium nitrate.

Urea, made from ammonia and carbon dioxide, is also a useful fertilizer and source of nitrogen. Liquid ammonia, applied directly to the soil, is a more modern source.

The element phosphorous is usually obtained from some source of calcium phosphate such as phosphate rock or other minerals. The crushed rock must be treated with sulfuric acid to increase its solubility. While frequently bought and sold (under various trade names) on the basis of its available "P_2O_5" content, it does not actually contain this compound. For convenience and ease of comparison, the actual available phosphorus is computed to its "available P_2O_5".

Phosphate fertilizers also furnish calcium, one of the other needed elements.

Potassium was supplied in older days by using wood ash, or by the "leaching" (letting water dribble through it) of wood ashes. Today, Carlsbad mines supply much needed potash salts. Some also comes from California, and some from Chile.

INSECTICIDES: Insect life in many forms preys upon the products of the farmer. Virus pests, molds or fungi (plant life forms), or visible insects do their best to eat the food destined for your table. To combat this horde of freeloaders, the chemist has devised a long list of items to discourage them. Many of the compounds are "specific". That is, they attack only one particular kind of pest. Some are more general in nature, and kill rather indiscriminately. The list is constantly changing, and the names are long and difficult to pronounce, so it would not do much good to have you learn them. But you should know that modern chemistry, if the demand is large enough, can make to order any chemical to attack any particular pest that might annoy the farmer and his crops.

In turn, since many of the pests which attack our crops are rather tenacious in clinging to life, the insecticides, pesticides, and fungicides have been made more and more powerful. Some of them are not any too good for YOU, either. Therefore, it is more important today, than ever before, to THOROUGHLY WASH your fruits, vegetables, and farm products BEFORE you serve them or prepare them.

While the farmer is required to wash his crops before marketing, this is done on a large scale commercial basis and usually leaves some "residual" (leftover) insecticide material on the product. Caught in an economic squeeze play, the farmer and government are doing a poor job of protecting the public, and unless you carefully wash your own produce, you could become ill from the residual poisons.

A recent case in Tijuana, Mexico occurred where flour in a warehouse was stored next to some leaking insecticide, and the result was the death of about 15 children.

The farmer is helped today also through the use of weed killers which presumably let his crop keep on growing peacefully while destroying weed pests which would take up needed energy and room. Again, wash your produce.....

Modern chemistry has come up too with "defoliating" agents (which take off the leaves), and other chemicals to speed up or slow down plant growth. You can have larger strawberries, potatoes with a thinner skin, improved cotton fibers, and many other things not dreamed of a generation ago.

Many farm products today do not go directly to the housewife, but go into industry. They emerge in totally different forms in many cases. The little round soybean, for example, enters a huge plant where it is first cleaned, washed, and separated from stems, leaves, and other junk. It is then crushed between massive rollers and subjected to a prolonged bath in gasoline. The gasoline is, in turn, removed by distillation (leaving the soybean oil), the oil is sold for cooking purposes, candy making, margarine manufacture, and a few other uses.

When the oil is left for a few hours in settling tanks, another material is separated from it. This is called "lecithin".

It is edible, and has the unique property of acting as a "wetting agent" for fats and water systems. It thus is sold to the candy and margarine industry. In its effect, lecithin acts as an edible "detergent"--in fact, the only commercially useful one at present. Next time you buy a candy bar, look at the label and meet your new friend "lecithin", and know WHY he is in there.

What is left from our little soybean (and it's not much any more) is de-oiled, de-proteined, and de-lecithined; and consists mostly of non-nutritious "fiber". While not really of much use to anyone, there is still a little something remaining, so it is ground up and put into dog food, cattle fodder, candy, or anything else that the active imagination of people in the industry can concoct.

Thus, the poor hard-working farmer, who is trying to get a cheap feed for his cattle, buys back the leftover soybean which has almost all of the "goodies" removed by now. He also buys back (if he bothers to think about it) about 12% water (some of which came from the stripping process).

Well, if he doesn't read the label, that's his problem.....

The above is just one case where a farm product enters industry. There could be many more examples. Modern industry is more and more utilizing the scientists' brains and methods to turn honest food into "gimmicks". Since most city dwellers cannot raise their own food, they have no choice but to buy these botched-up substitutes; but they don't have to like it.

HYDROPONICS: Plants actually do NOT have to grow in soil if they can be supplied with all needful elements. In recent years, large crops have been grown in gravel beds, and more recently still, in solutions alone. This science is called "hydroponics". It offers tremendous hope to those countries with insufficient land-mass for agriculture, but is still in its beginning stages as an industry, except in certain specialized areas.

The growth of mold to make penicillin is literally a hydroponic process. And recent research has produced "single-cell protein" from one-celled plants grown on petroleum products. This may some day feed most of the world.

Thus the farmer has been helped very considerably in his battle against visible and invisible marauders by the "chemical warfare" constantly being waged in his behalf. In turn, he must keep up with the best and latest developments in his field. He has been helped also in boosting soil fertility, and has been provided with additional markets for his goods through industrial processes. And the future chemist will play a more and more important role in growing, protecting, and modifying the world's food supply.

FOOD FOR THOUGHT:

For a change, on this page the student will write five thought-provoking questions on the role of chemistry in agriculture:

1.

2.

3.

4.

5.

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 24--CHEMISTRY IN THE FOREST

For many city dwellers, the only time they see a tree at close range is at Christmas when they buy a small one at the local market and carry it to their apartment to light and decorate. Country people have a wider outlook, closer acquaintance, and more diversified usage for trees, ranging from fence posts to fuel.

The average person would guess that the prime use of lumber throughout the world is for construction purposes, but this is not the case. Most of the world's trees are cut for the more primitive and wasteful purpose of fuel for both heating and cooking. As you might expect, the more "backward" the country, the more this is done. The more advanced countries move a larger proportion of their wood into construction or manufactured articles. In the United States, only about 20% of the wood harvest is used for fuel, and much of this is supplied by waste wood, trimmings, culls, scrap, etc.

Construction usage does take a big slice of the wood harvest, and this jumps tremendously in times of war. During four years of World War II, military usage took enough lumber to build almost 10 million family homes. But even in peacetime, construction is the number one wood user. In the United States railroads and utilities (ties and phone poles) rank third after construction and fuels.

The chemist has entered this field of human endeavor, as he has every other, and two of his most important contributions have been "pulpwood" and "plywood". Wood pulp is the basis of paper and cardboard for books, wrapping paper and paper bags, writing paper, paper towels and tissues, construction papers, containers and almost all packaging items, and even cellophane. Unwoven fabric looking much like cloth and having much the same properties can be made from wood pulp, and is going into the field of clothing manufacture at present. In all probability, paper dresses will be a commonplace item five years from now.

Plywood, with which we are all familiar, is a sandwich of thin layers of wood glued together. The resulting material has properties which are more desirable in some ways than "whole" wood. For example, by gluing the layers together with the grains running in different directions we can avoid much "warping". We also gain greater strength from this, and can utilize unsightly and inferior wood on the inside where it will not show.

A particular type of plywood, where the outer layer of at least one side is of special beauty, is called "veneer". By this means, a piece of furniture can be made to look like an expensive wood, but actually contains only very thin facings of it. Modern reproduction processes can actually create a product with the appearance of wood grain on a thin plastic surface, and confer other desirable properties too. This can be backed up also with cheap plywood to give a good looking veneer.

So the chemist and the engineer have combined efforts to produce many of our common everyday paper, cardboard and lumber necessities from wood pulp or plywood processes. But their roles go much further than that.

In our southern states, the yellow pine is periodically "slashed" or "chipped", and the thick ooze from the cuts collected much like maple syrup in New England. The product from the pine, however, is not edible. It is called "oleoresin", and goes to a crude still for a distillation process. The product dripping from the condenser is turpentine which goes into paints, varnishes, lacquers, solvents, polishes for shoes and furniture, and industrial cements.

The thick resinous material left in the still becomes a part of many other things. It goes into laundry soaps, adhesive tapes, oilcloth, printing inks, wallboard, and many other products. Again the imagination of the chemist and the technology of the engineer have been combined to bring out a host of new and useful products from this natural resource.

In the early 1900's, German scientists developed more sophisticated distillation processes that converted wood into acetone, alcohol (the poisonous kind), and charcoal. There are many other distillation products obtainable, but the products mentioned above are the products with a high percentage of yield from the process.

Even in the field of basic construction materials, giant strides are being made. By making "veneers" in which the inner portions of the sandwich are made from corrugated wood pulp, or some plastic derivative, it is possible to obtain very lightweight panels with high strength factors. These find uses in boatbuilding and airplanes. Other recent research has been aimed at putting specially treated paper coatings over wood (in other words a paper covered plywood) which could combine cheap wood on the inside and weather-resistant beauty on the outside, plus extra strength gained from combining the materials across the "grain".

One of the greater ways in which our scientists help is by making products cheaper and more available. Building products of greater beauty and variety are available to us today at much less cost than a few years ago so that the average working citizen can afford them. Making products more cheaply also protects the profits of many commercial companies enabling them to compete successfully and stay in business.

The forest is carried into the home in two other forms of vast and growing importance. Wood pulp is mostly cellulose. By treating this chemically it can be converted to cellulose nitrate which was the first synthetic "plastic". As the name would indicate, a "plastic" substance is one that can be "formed" to assume useful shapes. Cellulose nitrate was used as the base for films in the early motion picture industry. Since it is highly flammable, it presented a substantial fire hazard, and was replaced eventually by the less hazardous cellulose acetate.

From this humble beginning in 1870, the plastics industry has grown into a lusty giant and one of the world's largest basic industries. Besides using plastics for their own good properties such as light weight, durability, resistance to most liquids (including dilute acids and bases), strength, etc., plastics can be used often to replace more expensive or less available materials.

In many instances plastics have replaced metals at a big saving in cost and weight. More will be said about plastics in a later chapter, but right now we need to know where their "raw materials" come from.

The other vast new growing industry is that of synthetic fibers. As this name indicates, a fiber is a "stringy" type of material (like cotton) which can be woven into cloth. Wool and cotton were the natural fibers of the ancient world, and of course are still with us today. But fibers made artificially (synthetic fibers) are replacing natural fibers very quickly.

Synthetic fibers can be made from a variety of sources, but many of them start as a tree in the form of wood cellulose. The first artificial fiber was rayon. Synthetic fibers with the proper qualities are woven on looms into cloth, exactly as are the natural fibers. However, they may have other qualities which are superior to the natural materials such as crease resistance or resistance to soiling.

We have mentioned already "unwoven cloth". This material can be made from either natural or synthetic fibers, and represents a stage between woven cloth and paper. Literally, it is cloth made on a paper-making machine, rather than a loom. While it usually is not as strong as woven cloth, it can be used in many ways where strength is not a prime necessity. Fine looking tablecloths, napkins, and towels are already on the market in this type of material, and as mentioned, women's dresses are beginning to make their appearance.

Again, we will have more to say later regarding artificial fibers.

Would you consider eating a wood steak? Sawdust and waste wood can be converted into sugar and protein substances. The taste leaves something to be desired, but the nutritive value is right up to par. These substances can be used as cattle feed and end up as a steak on your table. And with further time and effort, the chemist will be able to improve the flavor so that you will want to eat wood-derived protein directly.

The bonding material which holds wood fibers together in the plant is called "lignin". For many years a waste product from the manufacture of wood pulp, research is showing now that lignin, also, can be used in many useful ways. Lignin can be used as an adhesive in making laminated paper or wood products, as a toughening agent for concrete, as a soil conditioner, as a binder in molded wood products and road materials, and in many other ways.

Wood itself can be improved by chemical treatment. Creosote applied to wood products (usually under heat and pressure) greatly prolongs their life, especially that of wood in contact with the earth. Fence posts and utility poles thus treated last much longer without rotting. Another process impregnates wood with phenol and formaldehyde (two "organic" chemicals). The result is the formation of a sort of internal combination of wood and plastic which has properties superior to either one alone. One of the most valuable uses for such treated wood is in the building of precision models to use as patterns for molding metal parts. The treated wood is much less influenced by changes in size due to humidity and temperature.

The actual process by which wood is converted into paper is rather simple. Basically, it consists of cutting the wood into chips by machines, and then cooking them in a solution of sulfurous acid. This dissolves the lignin, allowing the cellulose fibers to separate. Other chemicals may be added to bleach the wood pulp. The pulp is subjected to mechanical "beating" to make it very uniform in texture, and then allowed to flow out in a flat, continuous stream onto a belt made of wire screening. This allows the pulp to drain and dry. It then goes between polished metal rollers to remove the last of the moisture, and to give it a smooth surface.

Many special papers can be made. For example, a paper containing a rust preventative is used to wrap machine parts in storage. Fruit can be wrapped in paper containing fungicide or insecticide to prevent its attack by molds or insects. Heavy papers treated with tars or resins are used as roofing and building papers to keep out water and moisture. Paper can be "plated" too by bonding metal foils of different kinds to one or both sides. It can be used to make special containers for such items as food or liquids. Waxes are used also to impregnate paper to make it liquid-proof. In recent years the glass milk bottle has been replaced by the waxed milk carton.

Papers can be made to reflect heat or light, and are used frequently for their insulating properties. The ice cream you carry home from the store may be in an insulated paper bag which prevents it from melting before you get home.

The tremendous growth in the industries derived from our forest products is an excellent example of the value of "basic research"; that is, research done for the purpose of answering the question "WHY", rather than just for purposes of practical application. Basic research supplies us with important basic knowledge regarding man's environment, and this in turn is eventually applied to useful human applications. But always remember that the basic research has to precede the application of human knowledge.

Scientists working in universities on advanced degrees, and scientists teaching in such universities, are one of the largest sources of basic research. They devote years and lives unselfishly to finding the basic answers to the problems of the universe, and you and I reap the benefits in enriched human living experiences.

Some very large companies also conduct basic research, and today most of the world's governments carry out basic research in government laboratories. The total result is an "information explosion" which staggers the imagination. It presents a problem to the teacher because there is more material to teach, but no more time in which to teach it.

Pressed wood panels, insulating board, synthetic fireplace logs, and "reconstructed" wood boards are today all commonplace items which start with raw materials from the forest.

The forest, unlike mineral resources, is not necessarily a "one source" crop. Wise harvesting and wise replanting can and do extend this natural resource to the point where it can become a continuous supply of raw materials for a growing world. The chemist contributes added know how in protecting the growing crop from insect and mold attack, in increasing growth rates, in improving soils and fertilizers, and in many other ways.

It has been said that "wood.....may become civilization's most significant raw material" (Mr. Luther O. Griffith of the National Lumber Manufacturer's Association). Certainly, with its derived products, wood is assuming a very large place in our daily lives as civilization finds more and more uses for this versatile material.

FOOD FOR THOUGHT:

1. Look around the classroom and discuss each item that you see made of wood or derived from wood as a source.

2. How many different kinds of paper can you see in the classroom?

3. With a probable wood shortage in the future, how could the schools help in recovering some wasted wood products?

4. Look up some references about the "Naval Stores Industry". Which of the products in this industry might be used still aboard naval vessels?

5. Look around your classroom and see what items made at present from other materials could be made from wood derived substances.

6. How has chemistry helped fight forest fires? Think this through in every way possible, and discuss it.

7. Compare the construction of today's large airplanes with that of a few years ago with regard to forest derived products.

8. Think about, and compare fully, a primitive man's use of forest products as compared with modern man's use.

9. Discuss the use of a forest as a "watershed". Why is this important?

10. Why should unwoven dresses cost less than those made of woven cloth? What might be some of the disadvantages of unwoven dresses or suits?

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 25--THE HALOGENS--A CURSE OR A BLESSING?

In many cases, the chemist has found that he can arrange certain of the elements into "families? because the members bear a close relationship to each other. Such a family are the "halogens". They are a very versatile family, and a very controversial one. Whether they do more human harm than good is an open question, but as the song says, "I can't live without you, baby". No more can we as human beings exist without these elements.

Let us take a look at some of their common properties before we go further:

1. Their oxides (except for Fluorine, which doesn't combine with oxygen) form acids so the elements are all non-metals. In fact, they are very typical non-metals.

2. Each of the halogen elements can combine with hydrogen giving a gaseous product which yields an acid when dissolved in water.

3. The halogen elements are all colored.

4. The halogen elements are all highly reactive. Thus, the elements are never found in the free (uncombined) state in nature, but always in a compound.

5. Each halogen element is found in Group VII of the Periodic Table. Thus they all have seven electrons in their outer shell; and would like to pick up one more to make a stable shell of eight.

Well, it's an interesting family. Just WHO are they? There are five of them; four very abundant and well-known, and the fifth so scarce that it has not been found yet in nature (but can be made by nuclear reactions). From the lightest to the heaviest element they are: Fluorine, Chlorine, Bromine, Iodine, and Astatine.

Fluorine and Chlorine are gases at room temperatures, and are pale yellow (Fluorine) and yellow-green respectively. Bromine is an orange-brown liquid, and Iodine is a purple solid. In the gaseous state a molecule consists of two atoms; thus we write F_2, Cl_2, etc. Let us take these elements on an individual basis:

FLUORINE: Fluorine is so reactive that it is very difficult to obtain it as an element, and must be made by an electrolytic process. As an element, it is so reactive chemically that it cannot be stored even in glass bottles because it reacts with the glass! It reacts explosively with hydrogen, even in the dark; and so violently with powdered carbon (charcoal), sulfur, phosphorous and some other elements that they catch fire spontaneously. The compound formed with hydrogen, HF, dissolves in water to give hydrofluoric acid (similar to the hydrochloric acid you are familiar with).

A special word about hydrofluoric acid. It attacks glass so easily that it is the only practical material used for etching glass. But it is EXTREMELY DANGEROUS TO HANDLE OR BREATHE. A relatively weak 10% solution of hydrofluoric acid can penetrate the skin directly to the bone, and damage the bone. You can imagine what it can do to the lungs. Some household cleaning products actually have been sold containing a 10% solution of this acid, so READ THE LABEL. This acid is sold and stored only in bottles made of WAX.

The sodium salt of this acid, sodium fluoride, is also a violent poison used in ant and roach insecticides. It never should be left near small children.

Compounds of fluorine with hydrogen and chlorine, due to their physical properties, are useful as "refrigerants".

CHLORINE: This element sounds as if named after a chorus girl. However, it is a hard working and very important member of the Halogen family. It is a heavy, green-yellow gas, and has the dubious honor of being the very first poison gas used in warfare (WW I). Since the winds are not always under man's direct control, the whole idea sometimes backfired on one's own troops. Thus, in general the use of poison gases is not looked on with great favor by military strategists.

Chlorine can be made in the lab (and we will do so) by reacting manganese dioxide with hydrochloric acid with heating. The equation is:

$$4\ HCl + MnO_2 \dashrightarrow Cl_2 + MnCl_2 + 2\ H_2O$$

Commercially, this method is too expensive, and chlorine is made by the electrolysis of salt brine (sodium chloride solution) as you learned in a previous chapter.

Chlorine is almost three times as heavy as air, and quite soluble in water. Thus, when made in the lab, we do NOT collect this gas by displacement of water out of a bottle, but by displacement of AIR.

Chlorine, when inhaled, dissolves in the moisture of the mucous membranes, causing irritation. Large amounts, of course, could be fatal. In the lab, make sure that you use the HOOD, or some other device, to avoid your breathing in any significant amounts of this gas.

Like fluorine, chlorine is also quite reactive. It combines with hydrogen (explosively in the light) to give hydrogen chloride, which dissolves in water to form hydrochloric acid (one of the great necessities of modern industry).

Chlorine itself dissolves in water to give a mixture of two acids:

$$Cl_2 + H_2O \dashrightarrow HCl + HClO$$

The second acid, HClO, is an "oxygen-containing" acid called "hypochlorous acid". It is the active ingredient in many household bleach products. This is why moist chlorine gas is also a good bleaching agent.

Since chlorine is so reactive, it tends to oxidize invisible bacteria, and thus is used to purify drinking water and swimming pools. Since the residual taste would not be desirable, the chlorine is removed by "aeration"--just spraying the water in sunlight and air.

Chlorine, being an effective bleaching agent, is used to bleach, or "decolorize" wood pulp for the paper making industry, as well as natural cloths and fibers. Phosgene, $COCl_2$, and Mustard Gas, $(C_2H_4Cl)_2S$, are both extremely toxic and harmful gases which replaced elementary chlorine gas as military weapons. CCl_4, carbon tetrachloride, is a very useful solvent (for example in dry cleaning) and is non-flammable. It is used also in certain fire extinguishers for fighting electrical fires. However, always remember that it also is VERY TOXIC when inhaled.

In contact with hot metals it can form phosgene gas, so its use as a fire extinguisher should be looked at with a very critical eye. To the person using it in a confined space to put out a fire the cure could be worse than the disease!

A close relative of carbon tetrachloride is Chloroform ($CHCl_3$), useful as an anesthetic. Chlorine can combine with other compounds containing carbon. For example, Chlorprene is a "chlorinated" rubber which is more resistant to solvents, fats, and oils than natural rubber. It can be used for gasoline hose and other applications where natural rubber would be unsuitable.

Table salt is sodium chloride, and is considered a necessity to support human and animal life. The ancient world considered it so valuable that it was frequently used as "money", and the ancient trade routes were established with regard to the availability of salt. Savage tribes killed and traded for it. Even today in some Eastern countries, if you partake of salt with another person, you are not supposed to turn around and kill him, in token of the honor he has conferred upon you.

While the usual valence of chlorine (like most halogens) is MINUS ONE, conferred by picking up an extra electron, these elements can also lose their seven electrons one by one, thus showing a variety of POSITIVE valences. The most common compounds involved are the oxygen acids. Like hypochlorous acid (mentioned above), they all tend to be chemically UNSTABLE. Therefore, you rarely will see a bottle labelled "PERCHLORIC ACID", or with the names of some of the other halogen oxy-acids. They are useful all right, but we usually make them just as we need them, due to their instability. And we don't make much at a time because they might explode.

BROMINE, The "Element From the Sea": Ocean water, and some inland salt beds or salt brines, contain an appreciable fraction of bromine compounds as well as those of chlorine. To recover the element Bromine, the brines are first "concentrated" and then treated with elementary Chlorine. The bromine is replaced from its compounds by the more active Chlorine, and separated out from the brine or can be distilled off.

Bromine is a very heavy liquid (density = 3.12) which boils at 58° C to become a heavy red-brown gas. It is bad for the lungs, and also dangerous to the skin, causing severe burns.

Like Chlorine, bromine forms a gas with hydrogen which dissolves in water to become HYDROBROMIC ACID. The element or the acid will react with many metals to give "bromides" (such as potassium bromide) which are used in medicine to reduce nervousness. Their use should be carefully controlled by a doctor because they are poisonous in excessive doses.

Most of the elementary bromine produced in this country is used in making lead tetraethyl for anti-knock gasoline. Despite its utility in powering high-compression gasoline engines, lead tetraethyl is a violent poison which can be absorbed directly THROUGH the skin. Avoid frequent contact with gasoline, either on the skin or breathing its fumes. Silver bromide is used in black and white photography. Bromine in combination with certain organic compounds can make "tear gas". This is a type of gas that causes the victim to cry and be irritated to the point of helplessness while not causing any permanent harm. It is used on criminals, in riot control, and even in actual warfare situations.

Like Chlorine, Bromine can react with some compounds of carbon. Ethyl Bromide (C_2H_5Br) is an example. Compounds of this type have been used as insecticides and pesticides on stored grains.

IODINE: The element, at room temperature, is a purplish and metallic-looking solid. Gentle warming converts it to a deep purple vapor, WITHOUT going through a liquid state. Cooling the vapor will again convert the iodine to a purplish SOLID, without becoming a liquid. The process of going directly from a SOLID to a VAPOR state (without first becoming a liquid) is called "SUBLIMATION".

Iodine is not very soluble in pure water, but will dissolve in solvents like Chloroform, Carbon Tetrachloride or Alcohol. It can be used to disinfect small cuts or wounds, but has been replaced by other things because it "stings" when applied.

Like chlorine and bromine, it reacts with hydrogen to form Hydrogen Iodide (HI) which dissolves in water to give Hydriodic Acid. Iodine also can form acids with hydrogen and oxygen, and also salts of such acids. However, their use is limited.

Apparently just as some chloride ion is necessary to human life, so is a SMALL amount of iodide ion. A condition known as goiter appears to be caused by a deficiency of iodine in the diet, and can be corrected by feeding iodine in small amounts. Since iodine compounds are present in sea water and sea creatures, people living near oceans usually don't have such a problem. However, people living far inland sometimes do. This is why you can buy "IODIZED SALT' in your local grocery store.

Silver Iodide is used in photography, particularly in making film sensitive to X-Rays (such as your dentist uses). In making films, the silver compound is finely ground, mixed with gelatin, and put on a transparent cellulose backing. Bright light furnishes radiation energy which decomposes the silver compound and forms elementary silver. The silver formed is opaque, and will not let light through it. This process makes a "photograph".

ASTATINE: This fifth member of our Halogen Family is not well known because it can be made only in small amounts through nuclear reactions. However, its properties are similar to the other halogens. The future may call forth greater production if uses are found for this element.

In most of the reactions we have mentioned, it is desirable to know that the chemical "reactivity" varies from Fluorine (MOST reactive) to Iodine (LEAST reactive). This difference in reactivity also gives rise to a "series" where an element which is MORE reactive can replace a LESS reactive one in its compounds.

This is why elementary Chlorine, applied directly to concentrated sea water or brines containing bromine compounds, can replace bromine in these compounds, and release the bromine as the element.

A very interesting "Family", these halogens. From medicine to poison gases, from picture taking to insecticides, they make a colorful contribution to man's environment. As to whether they are friend or foe, it depends upon the use to which man puts them. But they are here to stay, and we could not do without them.

FOOD FOR THOUGHT:

1. Fill out the following table:

	FLUORINE	CHLORINE	BROMINE	IODINE
SYMBOL				
ATOMIC WEIGHT				
COLOR				
PHYSICAL STATE				
ELECTRONS IN OUTER SHELL				
CHEMICAL REACTIVITY				

2. WHY are the halogens called a "family" of elements?

3. What is the physical state of each of the halogen hydrides (except for Astatine which is not given)?

4. Sulfur vapor can go directly also from the vapor to the solid state. What is this process called? Could this be used as the basis of a purification process for certain substances? Discuss.

5. How does the physical state of the element, and its color, change with increasing atomic weight?

6. If fluorine and fluorides are so poisonous and dangerous, just how is it that we can put them into toothpaste safely?

7. What general class or type of impurities in water can be removed by "aeration"?

8. Modern warfare is aimed more at wounding or maiming the enemy rather than merely killing him. WHY is this the case? This being so, discuss the military value of poison gases as compared with bullets.

9. If lead tetraethyl is a poison and can be absorbed through the skin, why are people careless in handling gasoline?

10. In terms of the relative SIZE of each type of halogen atom, discuss just WHY their chemical reactivity should be in the order discussed in this chapter.

11. Just because a product is sold openly in the stores can you safely assume that it is harmless under all conditions of usage? Discuss this fully.

12. Obtain and bring to class: 1) a can of drain cleaner, 2) a bottle of window cleaner, 3) a jar of oven cleaner, 4) a can or jar of metal polish. DISCUSS the ingredients (as the label gives them) in terms of human hazard. Just how much and what kind of warnings do they give you on the label? Is any "antidote" suggested for some products?

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 26--REACTION KINETICS AND CONTROL

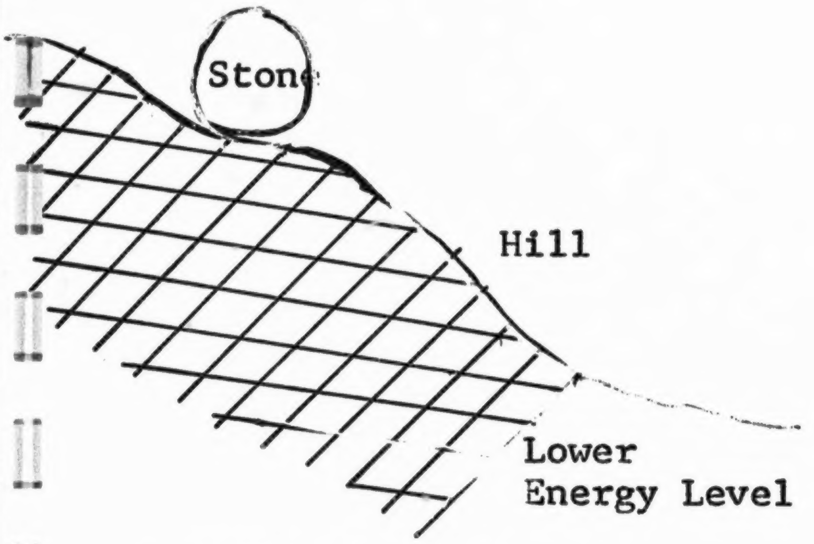
The above chapter title introduces a new word, but don't let it worry you. The word "kinetics" refers to movement; so "reaction kinetics" refers simply to "what makes reactions go".

We already know that certain chemicals will react together, and others will not. WHY should this be the case? Well, let us take a simple parallel concept and look at it.

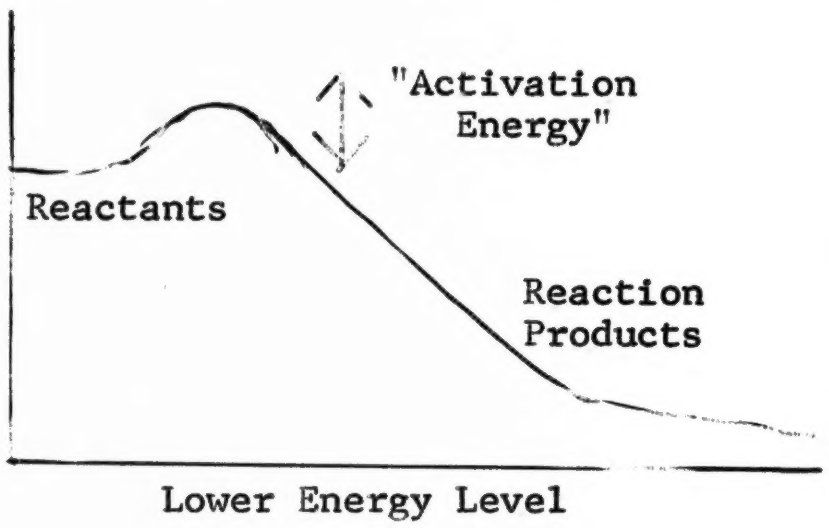
A stone sitting on a hillside may roll downhill if it is subjected to a slight disturbance. If you stop to think about it, in the process described it is going from a state of higher energy to a state of lower energy. Also, this is true for chemical reactions.

If two (or more) substances can, by reacting together, achieve a state of lower energy, then they have the possibility of undergoing a chemical reaction. Other reasons may prevent the reaction from taking place, but the possibility is there.

Like our stone, however, most reactions also have to be given a "push" to get them started even when the conditions fulfill the energy requirement mentioned above. This starting energy, or "activation energy", is usually small compared with the energy change for the whole reaction. In the case of the stone, wind and rain have combined to create a small "depression" in the ground which gives it a temporary stability, and again the "push" required to start it rolling downhill is usually very small compared with the total energy change involved. To show this graphically:



A STONE ON A HILL



A CHEMICAL REACTION

This "activation energy" to start a chemical reaction can be provided in several ways. Since raising the temperature of a material increases the motion of its atoms and molecules, this is one way. Also, since certain electromagnetic wavelengths (both visible or invisible) can increase the motion of atoms and molecules, this is another way. Increased mechanical motion also can be imparted directly to reactants, and thus start a reaction.

To show you how important this "activation energy" can be, let us take a look at the atmosphere around us. It contains nitrogen and oxygen, and it is possible to react these two elements directly with one another to form oxides or nitrogen (which are fairly poisonous). In that case, why should there be any oxygen left for us to breathe? Simply because the "activation energy" required to start this reaction going is unusually high. If we want to combine these gases, we have to provide a high temperature of several thousand degrees. Since nature itself does not supply the "activation energy" ordinarily, the reaction won't start, and we have oxygen left to breathe.

As a matter of fact, a bolt of lightning CAN and sometimes DOES provide such activation energy, and after a nearby thunderstorm you may be able to detect oxides of nitrogen in the air.

In the chapter on Halogens, you learned that the various halogen elements all combined with hydrogen, but with differing degrees of reactivity. Fluorine reacts explosively with hydrogen, even at room temperatures, IN THE DARK. Chlorine will do the same, but it has to be IN THE LIGHT. Bromine and Iodine require even more stimulus to get the reaction started. This gives you a practical idea of the influence of "activation energy" on starting a chemical reaction.

You have seen already, in the laboratory, several reactions that are "activated" by an increase in temperature. For example, you had to apply heat to your mixture of manganese dioxide and potassium bromide to make Bromine.

A rifle shell can be stable and inert for many years. Yet when the firing pin hits the edge (or center) of the shell, it goes off. In this case, a small amount of an unstable mercury compound is exploded when struck mechanically. This is an example of the activation energy being furnished directly by mechanical motion, thus starting off a chemical reaction.

All right, now we have our reaction started. What next? Can we influence its rate, or speed? Of course we can.

Assuming the molecular theory of matter, usually we assume that atoms (or molecules) have to hit each other before they can react. (The converse assumption is also made that if the atoms or molecules DON'T collide with each other they WON'T react.) Obviously then, if we do anything to the reactants to make their atoms or molecules collide more often, we will speed up the rate of reaction.

In the light of kinetic theory, an increase of temperature results in faster molecular motion and more frequent collisions. It therefore should and does increase the rate of a chemical reaction.

By the same token, an increase of pressure brings all the atoms or molecules in a system closer together, and also results in an increased number of collisions and an increase in reaction rate.

DON'T confuse "activation energy" (the energy needed to get a reaction started), with the influence of temperature on the rate of the reaction itself. They are separate and distinct from each other.

You have learned already about catalysts. These substances affect the rate, or speed, of a chemical reaction also. Either they can speed up, or slow down, a chemical reaction. Catalysts may work in several ways. Sometimes they also have an influence on the activation energy required to get a reaction started.

How about the "concentration" of the reacting substances? Obviously, if the concentration (that is, the amount per unit volume) is very low, the reactant molecules will get very little chance to collide with each other and possibly react. So the concentration of the reacting substances is a very definite factor in the speed of a reaction. The lower the concentration, the slower the reaction; the higher the concentration, the faster the reaction.

To summarize the above, we have four ways of affecting the speed, or rate, at which a chemical reaction goes:

1. temperature
2. pressure (if a gas is involved)
3. catalysis
4. concentration of reactants

Well, now we have a reaction proceeding. What happens next?

In some cases, we find that reactions continue until the original reactants are all "used up". In many other cases, reactions go only up to a certain point, and then seem to "stop". In other words, they get to a "state of equilibrium".

From our knowledge of kinetic-molecular theory, we know that molecules and atoms are in constant motion. Thus, even when a reaction seems to stop, this does NOT really represent a static condition. Equilibrium in a chemical reaction is a dynamic condition where in reality the reaction forwards is proceeding just as fast as the reaction backwards.

A very excellent reaction to take as an example is that of the direct combination of hydrogen and nitrogen (the latter element from the air) to make ammonia. In this case, all of the elements involved as reactants or products are gases. The equation for the reaction is simply:

$$3\ H_2 + N_2 \dashrightarrow 2\ NH_3$$

You can mix the two "reactant" gases (the hydrogen and nitrogen) in the same vessel and wait practically forever for something to happen. But, by raising the temperature (providing more collisions), and raising the pressure (providing more collisions), and providing a catalyst (in this case powdered iron plus potassium and aluminum oxides), we can get the reaction to start making ammonia at a reasonable rate.

NOW, suppose that we are doing all this in a totally CLOSED system; that is, a system from which none of the gases involved can escape. The physical picture would go something like this:

1. At the beginning of the reaction, there would be only molecules of hydrogen and nitrogen gas. These would sometimes collide, and some of the collisions (not all) would be fruitful in producing molecules of ammonia gas.

2. As the reaction continues, there would be more and more molecules of ammonia gas, and fewer and fewer molecules of hydrogen and nitrogen gases. Thus, there would be fewer molecules of ammonia produced. Also, once in a while an ammonia molecule itself would collide and break apart again to form hydrogen and nitrogen gases.

3. Eventually, the number of collisions of hydrogen and nitrogen gases resulting in forming an ammonia molecule would be "balanced" by the number of ammonia molecules breaking apart again to form the two elementary gases.

At this point, an observer looking at the overall scene would say that nothing is happening because no further hydrogen or nitrogen appears to be used up, and no further amount of ammonia gas is being formed. Actually, a state of "chemical equilibrium" has been reached.

However, this state of "equilibrium", as you can understand now, is definitely NOT static. It is NOT a state of no reaction, but a state of "balance" between the forward reaction (which produces ammonia) and the "backward" reaction (which produces hydrogen and nitrogen). It is very definitely a "DYNAMIC" situation, a situation of constant and continued activity. This is true for ALL CHEMICAL REACTIONS IN CLOSED SYSTEMS.

Now that you have some understanding of "equilibrium" of a chemical reaction just HOW and WHY do some reactions ever get out of this situation, and "go to completion"? There are three ways to do this:

1. escape of a volatile product (such as a gas)
2. formation of an insoluble product
3. formation of non-ionizable (or very poorly-ionized) product

In each case, as you will notice, one of the reaction products can "escape" in some way, thus removing itself from the vicinity of the reaction. Under such circumstances, naturally there will be little or no tendency for a "backward" reaction to take place since one (or possibly more) of the reactants would be lacking. Therefore, under these conditions such reactions will keep going "forward" (never reaching a state of "equilibrium") until they are essentially "complete". (All of the reactants have been used up.)

Let us look at some further things which can affect a chemical reaction. In the example given above, where ammonia gas is formed, note that the relative volumes of the reactants and product stand in the ratio of 2/1. That is:

$$3\,H_2 \quad + \quad N_2 \quad \dashrightarrow \quad 2\,NH_3$$

$$\begin{array}{cccc} \text{3 Volumes} & + \text{ 1 Volume} & \dashrightarrow & \text{2 Volumes} \\ \text{Hydrogen} & \text{Nitrogen} & & \text{Ammonia} \end{array}$$

It is an old maxim that "the squeaking wheel gets the grease". There is a parallel in chemical reactions in that they tend to "shift" in such a direction as to relieve any "stress or strain" on the system as a whole. Thus, if we were to put this reaction under high pressure conditions, it would tend to "shift the equilibrium" towards that side which would relieve the excess pressure, in this case, towards the right side.

For this particular reaction, an increase in pressure is doubly effective. It not only pushes all the molecules closer together so that they can collide and react more often, but it tends to "squeeze" the reaction towards the side which will produce more ammonia.

ANY chemical reaction where gases or vapors are concerned and where the relative volumes are UNEQUAL on both sides of the reaction can be shifted by raising or lowering the pressure. If the relative volumes on both sides of the equation are EQUAL, then the equilibrium will NOT be shifted by the pressure. Even in such cases, however, the condition of equilibrium will be reached SOONER by operating at higher pressures because it provides for more frequent collisions.

There is one other important factor regarding reaction rate which we have not considered yet. It is the "state of subdivision" of the reactants, and is a physical factor, rather than a chemical one.

If the individual atoms or molecules have to collide with one another in order to react, then the more "finely-divided" (the greater the state of subdivision) they are, the more opportunity for reaction to take place.

Sodium metal is so reactive that it will react with moist air very quickly. Even so, if we take a large cube of this metal (say 2" by 2"), it would take a matter of hours for complete reaction to take place. If, on the other hand, we cut the metal into small pieces, the air can get to each one more readily, and the reaction may take place in minutes.

This is true for all chemical reactions. A chunk of coal, for instance, may be rather hard to light. Yet the same piece of coal, powdered into small particles, can be exploded by even a spark (which is why they have to use spark-proof tools in coal mines).

For this reason, most of the faster reactions take place in solution where the various reactants are dissolved down to molecular dimensions, and therefore get a chance to react relatively quickly.

By the understanding of reaction kinetics, man has learned to control, for his benefit, many productive chemical reactions. Notice that such large practical benefits come from studying the BASIC facts about nature and its laws, without regard for immediate returns in the way of practicality.

FOOD FOR THOUGHT:

1. When an auto battery is charged, hydrogen gas is liberated from its cells. If the top of each cell were sealed so that this gas could not escape, just what might happen when you charged such a battery?

2. In Question 1, assuming that the battery "case" was made exceptionally strong so that it would not rupture under pressure, what might occur to such a sealed battery being charged, as far as reaction "kinetics" are concerned?

3. The reaction of burning Sulfur in air to produce Sulfur Dioxide can be shown:

$$\underset{\text{Solid}}{S} + \underset{\text{Gas}}{O_2} \dashrightarrow \underset{\text{Gas}}{SO_2}$$

For this particular reaction, if you put it under increased pressure in a closed system, what effect would it have on:

a. reaction speed (rate) before equilibrium was reached?

b. the state of equilibrium itself?

4. Explain why an auto battery may have trouble starting your car on a cold day, in terms of reaction kinetics.

5. The reaction of Sulfur Dioxide with Oxygen to produce Sulfur Trioxide is written:

$$2\ SO_2 + O_2 \dashrightarrow 2\ SO_3$$

a. If you want to produce more Sulfur Trioxide, would you use LOW or HIGH pressure on this reaction?

b. If you removed the Sulfur Trioxide as fast it was being formed, would that make the reaction go to completion to the RIGHT SIDE?

6. If you cut an apple and leave it exposed to the air, it turns brown. If you put the cut apple in a refrigerator, will it take longer before it turns color? WHY?

7. WHY does food keep longer in the refrigerator before spoiling?

8. WHAT ROLE does the oven play in baking a cake?

9. Adding a solution containing silver ion to one containing chloride ion produces an insoluble white precipitate of silver chloride. To make certain that you precipitate ALL of the silver ion out of a solution, would it help (according to reaction kinetics) to add a reasonable excess of chloride ion?

10. What effect do you think that high temperatures and high pressures would have on the "reaction vessels" or tanks used in industrial chemical processing? Discuss this.

11. How long do you think the brick lining would last in a steel-making furnace? Discuss this.

12. In terms of reaction kinetics, why does a match light when you strike it?

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 27--CERAMICS

The element Silicon, while too active to be found in nature in the free state, is abundant in the form ot its compounds. It makes up about 25% of the earth's crust. It is therefore natural that man has turned to silicon compounds as a low cost construction and container material. Bricks, cement, glass, and pottery items all start from silicon materials.

In nature Silicon is found mostly as Silicon Dioxide, SiO_2 (also called just "silica"), or as metallic "silicates".

Silicon Dioxide is the main ingredient of common sand and of quartz. Crystallized forms of Silicon Dioxide, colored by small amounts of impurities, form some of our most lovely gem stones (such as agate, jasper, onyx, amethyst, opal), and are shaped and smoothed for use in jewelry. The variety of such materials in our Southwest attracts tourists who buy the rock in both "rough" form or as finished pieces.

Silicon Dioxide is very hard; harder than glass, in fact, but not as hard as diamond. Driving through a sandstorm at high speed your windshield will be subject to the cutting and chipping action of such silica particles, and will become pitted quickly and less transparent for driving.

Silica is not affected by most chemical reagents, but it can be attacked by hydrofluoric acid or by the action of alkali metal hydroxides or carbonates at very high temperatures (several hundred degrees). Thus you can "melt" silica or silicate rocks in a bath of molten sodium or potassium hydroxide or carbonate, literally. This is one way to put a piece of rock or mineral into solution so that it can be analyzed.

Pure silica (also called quartz) has two great advantages for use in scientific equipment and instrumentation: 1. Its expansion and contraction with changes in temperature are quite small. Thus, a quartz vessel can withstand large and rapid temperature changes without breaking due to "thermal shock". Modern Pyrex laboratory and household cooking ware contains a larger percentage of silica, and thus is better able to withstand temperature changes. 2. Silica (quartz) is very transparent to ultraviolet light rays. Thus, quartz lenses, prisms, and containers are used for instruments such as spectroscopes which are designed to work in the ultraviolet light region.

Hydrated Silica gives an acid substance called Silicic Acid, H_2SiO_3. Thus, Silicon is a typical non-metal. Most metallic silicates found in nature can be considered as metal salts of this acid. The sodium salt, Sodium Silicate, is sold in water solution as a thick, syrupy liquid under the name "Water Glass". It finds uses in preserving eggs, fireproofing wood and cloth, as a cement in mending pottery and glass items, and as a "filler".

Silica, in the form of a pure sand, is reacted with sodium carbonate, calcium carbonate, and sometimes other minor reactants, all melted together at high temperatures, to form "glass". Colored "glasses" have been found also in nature as the result of volcanic action. They are sold as gem rock under the name "Obsidian". The same material was used by primitive Indian peoples in making tools of various kinds.

Glass can be colored by the addition of small amounts of metals such as iron, manganese, gold, or selenium. Other properties also can be modified by the addition of certain elements. Generations ago most glass items were made by hand (even window glass). Like everything else, the machine age has entered the glassmaking industry and produced items in large quantity at low cost.

In recent years the glass container field slowly is being taken over by the plastics industry; one of the chief advantages of the latter products being light weight.

Clay is mostly impure aluminum silicate in finely divided form. When mixed with water, clay forms a plastic mass which may be shaped easily. Upon drying, it retains its shape and shrinks slightly to a hard mass. These properties make clay useful as a building material for making bricks. After drying, bricks usually are "fired" to a fairly high temperature in a furnace. This causes some of the lower melting materials present to fuse together, thus acting as a binder to hold the brick together against the ravages of wind and weather.

Purer forms of clay, quartz and ground "feldspar" (feldspar is a double silicate of either sodium or potassium silicate plus aluminum silicate) mixed with water and formed either by hand or by shaped molds are made into the higher grades of "china" or "porcelain". After firing, usually they are coated with a "glaze" material, and refired to give them a glossy finish. Also they may be hand painted or machine decorated, using mineral colors to withstand the high temperatures involved.

If we mix together a mixture of clay and limestone (mostly calcium carbonate) in finely divided form, and then heat this mixture until it just begins to fuse, we get a product called a "clinker". The lumps of "clinker" are ground then with a small amount of calcium sulfate to a very fine powder to make "cement". Cement is literally the very foundation of our modern civilization.

When cement is added to water in the proper proportions, and the mixture allowed to "set", a hard rocklike mass results. The chemical action is complex, but does depend upon the formation of tiny silicate crystals which interlock in all directions to make a product of high strength and durability.

When sand and crushed stone are added to the mixture of cement and water, we call the result concrete. The additives are present partly just as "filler" (to extend the bulk and cheapen the product), and partly to impart desirable qualities such as increased strength.

Concrete and cement will set under water as well as in dry air; thus being used in underwater locations such as bridge supports and dams.

Tremendous amounts of concrete are used in the construction of buildings, dams, and roads all over the world.

The setting time of cement can be controlled somewhat by the addition of chemicals and other additives can be used for other purposes. An expanded mineral sold under the name of Vermiculite can be used as a bulking agent. It makes the overall density much lower. Steel bars or nets can be imbedded in cement or concrete to increase the strength. This is called reinforced concrete.

Concrete can be poured into large molds to form "concrete blocks". Similar building blocks can be made using ground cinder materials bound together with cement. This product is called "cinder block".

Calcium sulfate, while not a silicon material, is also abundant and used as a building material. It is heated to lose its water of crystallization, and sold as "Gypsum". When mixed with water, it also forms a plastic mass which eventually hardens.

Usually Gypsum is used for inside finishing sandwiched between two cardboard layers to form what is called "wallboard". It is quite brittle in dry form, and not very strong.

One other material of great industrial importance is made from silica. Silicon Carbide (also called Carborundum) is made by reacting Silica and Carbon (as Coke) in an electric furnace according to the reaction:

$3\ C + SiO_2 \dashrightarrow SiC\ \ 2\ CO\uparrow$

Silicon Carbide when pure is an almost colorless solid, but the usual commercial product is a gray or black. Its main virtue lies in its hardness since it is one of the hardest substances known to man. Even though not as hard as the diamond, it finds extensive use in grinding wheels and for rock and cement drills. When he fills your teeth, your dentist will be using a small "burr drill" with a silicon carbide tip.

Modern industrial technology is completely dependent upon the grinding wheel and drill for precision finishing and drilling. The process for making Silicon Carbide thus has contributed greatly to the growth of the modern world and the machine tool industry.

Note that ever since primitive times man has turned to the naturally abundant silicon compounds to help provide shelter and tools.

FOOD FOR THOUGHT:

1. What is the chief reason why the silicon compounds are used in the building and ceramic industries?

2. Why use bricks or blocks for building houses, rather than natural stones?

3. Discuss what might be some disadvantages of using plastic containers for packaging different kinds of products.

4. Why do you suppose that brown colored glass is used to contain certain kinds of drugs or medicines?

5. Do you have any particular kinds of silica-containing gem rocks in your area? If so, what?

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

CHAPTER 28--CARBON COMPOUNDS--THE CHEMISTRY OF LIFE

So far, you have been exposed only briefly to two common carbon compounds: 1. Carbon Monoxide, CO, odorless, tasteless, and extremely poisonous (this is the gas produced from an auto exhaust), and 2. Carbon Dioxide, CO_2, odorless, tasteless, non-poisonous but won't support life (this is the gas in your soda pop).

The element Carbon, having four electrons in its outer shell, is in a unique position as far as its bonding with other elements is concerned. Carbon atoms can combine also with other carbon atoms, thus making combinations of long "chains". In addition, it is capable of forming bonds with other atoms in which the valences appear to be not fully "saturated", leading to "double" and "triple" bonds between the carbon atoms. Compounds involving such "unsaturated" double or triple bonds are usually unstable and highly reactive. Therefore they tend to add other atoms very easily.

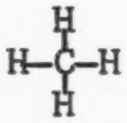
Thus, the fact that carbon atoms can exhibit several kinds of forces towards holding other atoms (valence forces or bonding forces) and can combine with themselves results in a complex situation in which a tremendous variety and number of compounds can be formed. All of the inorganic compounds (this is what we have studied so far) number only a few thousand whereas there are between a quarter million and a half million known organic carbon compounds.

About two hundred years ago it was believed that all of these carbon compounds were associated with life processes and could be made in no other way. But today, their "synthesis" is not only possible, but carried out on a wide scale. In fact, we have made thousands and thousands of organic compounds which were totally unknown in nature.

The fact does remain that all living things, from one-celled animals and plants up to man, do involve carbon chemistry, or organic chemistry. Due to the variety and complexity of organic reactions, their study is more complicated than inorganic chemistry and is in fact the topic of advanced courses in chemistry. However, a brief exposure to this topic is very desirable to you at this point.

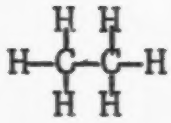
The simplest kinds of organic compounds are the "hydrocarbons". They involve only two elements (hydrogen and carbon) which are formed in "chains" which range in size from a few atoms up to many thousands. The "chains" can be either "straight" chains or 'branched' chains. Thus we can have compounds with the same formula (the same number and types of atoms) but different arrangements in space. Typical examples are the following:

METHANE



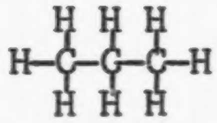
$$H-\overset{H}{\underset{H}{C}}-H$$

ETHANE



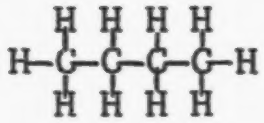
$$H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$$

PROPANE



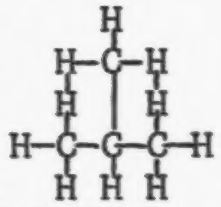
$$H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$$

BUTANE



$$H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-H$$

BRANCHED-
CHAIN
BUTANE



(Called ISO-BUTANE)

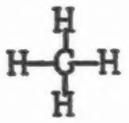
As we increase the number of carbon atoms in the chain, we increase the number of possible places for "branching", and therefore increase the number of spatial arrangements possible. You can see that with a chain of a hundred carbon atoms several hundred different spatial arrangements might be possible. This shows the tremendous complexity of the field of organic chemistry.

Notice that two of the hydrocarbons probably are already familiar to you. Propane and Butane are gases used for cooking and fuel in rural areas since they can be kept under pressure easily in metal tanks for use as desired. Notice also that they are composed of only two kinds of atoms (hydrogen and carbon), both of which can combine with oxygen and give out heat in the process (exothermic reactions).

The first few members of this series are gases. Starting with Pentane (five carbon atoms) they are liquids. With more and more carbon atoms they become waxy solids. Paraffin wax is a hydrocarbon used extensively as a waterproofing agent for milk cartons and other containers, and for sealing preserves at home. But all of the hydrocarbons belong to a sort of "family" called in organic chemistry a "homolgous series".

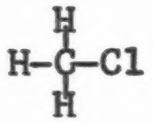
By various reactions, one, two, or even more of the hydrogen atoms in the hydrocarbons can be replaced by other reactive elements (such as the halogens). Using methane and chlorine as examples, we can have:

METHANE



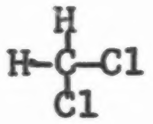
$$\begin{array}{ccc} & H & \\ & | & \\ H- & C & -H \\ & | & \\ & H & \end{array}$$

MONOCHLORMETHANE



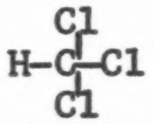
$$\begin{array}{ccc} & H & \\ & | & \\ H- & C & -Cl \\ & | & \\ & H & \end{array}$$

DICHLORMETHANE



$$\begin{array}{ccc} & H & \\ & | & \\ H- & C & -Cl \\ & | & \\ & Cl & \end{array}$$

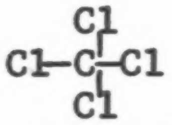
TRICHLOROMETHANE



$$\begin{array}{ccc} & Cl & \\ & | & \\ H- & C & -Cl \\ & | & \\ & Cl & \end{array}$$

(Also known as Chloroform)

TETRACHLOROMETHANE



$$\begin{array}{ccc} & Cl & \\ & | & \\ Cl- & C & -Cl \\ & | & \\ & Cl & \end{array}$$

(Also known as Carbon Tetrachloride)

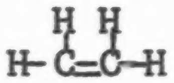
Similar substitution compounds are possible for both straight-chain and branched-chain compounds, and at any of the varied possible positions along the "chain". Just think of the multitude of possible compounds based on the possible combinations. No wonder that organic chemistry embraces so MANY different kinds of compounds.

Let us take a brief look at the change in properties of a "substituted" compound. As mentioned, any of the hydrocarbons can burn since the hydrogen and carbon they contain both readily combine with oxygen. Methane (also called "Marsh Gas" because it is formed by rotting vegetation) burns readily, and even explodes in the presence of oxygen if the proportions are right. But by the time you hook on a few Chlorine atoms to make Chloroform, it will no longer even burn. And with the fourth one in place to give Carbon Tetrachloride, you have a compound actually USED TO PUT OUT FIRES.

What a change in properties.

As examples of compounds which involve double or triple bonds, let us look at:

ETHYLENE



$$\begin{array}{cccc} & H & H & \\ & | & | & \\ H- & C & = C & -H \end{array}$$

ACETYLENE $H-C\equiv C-H$

Examples of compounds with "unsaturated" bonds

Acetylene gives a very HOT flame when it is burned in air or in oxygen, and thus is favored highly by burglars in opening safes with the "cutting torch". It also finds everyday usage in welding and metal cutting operations. Some of the heat energy derived from burning acetylene comes from the breaking of its triple bond.

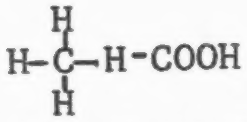
Acetylene is one of the compounds with a direct link to INORGANIC chemistry since it can be made from completely inorganic materials. By heating carbon (coke) and lime in the electric furnace we can get Calcium Carbide CaC_2, and when this substance is reacted with water, it gives the gas Acetylene. Even today, many underground miners depend upon their little acetylene lamp for light. Years ago, automobiles used such lamps as headlights.

Ethylene and acetylene are the simplest members of other "homolgous series" involving double and triple bonded compounds. Such compounds can have other atoms in place of the hydrogen atoms too, like the saturated hydrocarbons.

In inorganic chemistry the presence of ionizable hydrogen atoms on a compound made it an acid, and the presence of ionizable hydroxyl ions made it a base. In organic chemistry, an acid is made by the presence of a "Carboxyl" group (-COOH group), and a base by the presence of an [illegible] group giving an "alcohol". To give examples:

ORGANIC ACIDS

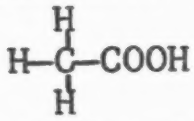
FORMIC ACID



$H-\overset{H}{\underset{H}{C}}-H-COOH$

This is the acid material in ant bites and insect stings.

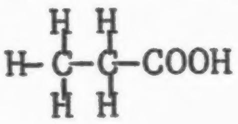
ACETIC ACID



$H-\overset{H}{\underset{H}{C}}-COOH$

This is the acid in vinegar.

PROPIONIC ACID



$H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-COOH$

etc.

Many of the longer-chain organic acids are known as the "fatty" acids because they are a component of fats and fatty tissue.

Organic acids, whether long or short-chain, can be neutralized by metal hydroxides. The product of this reaction, when the longer "fatty" acids are involved, is called a "soap". The soap you use for washing your hands is one of these products.

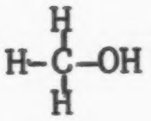
Sodium stearate (from sodium hydroxide and stearic acid) is usually the main ingredient.

Such "soaps" do NOT actually dissolve in water to form true solutions because the long-chain fatty acid is highly water-resistant (just like a hydrocarbon). However, they do "disperse" in water readily to form "colloidal" dispersions.

The main function of a "soap" or a "detergent" is to lower the surface tension of water, thus permitting water to surround every dirt particle easily, and allow the dirt to be floated away.

ORGANIC BASES (THE ALCOHOLS)

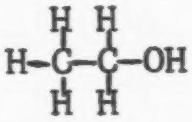
METHANOL



$H-\overset{H}{\underset{H}{C}}-OH$

Also known as Wood Alcohol because it can be made by the destructive distillation of wood. VERY POISONOUS, causing blindness, paralysis, and death if taken internally.

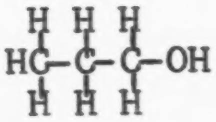
ETHANOL



$H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-OH$

Also called Grain Alcohol. This is the ONLY member of the series which is nontoxic in reasonable doses. Made from the fermentation of grain, using yeast as a catalyst.

PROPANOL



$H\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-OH$

Used as a RUBBING ALCOHOL in hospitals. Poisonous if taken internally.

etc.

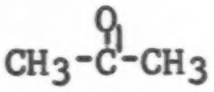
Remember that the addition groups to form acids and alcohols also can go on ANY of the hydrogen positions of either the straight-chain or branched-chain compounds. Therefore there will be SEVERAL butyl alcohols, several pentanols, several hexanols, etc.

To get even a beginning understanding of the field of organic chemistry, we should take a look at a few other organic groups which are fairly common and useful in everyday life, and which can be substituted onto almost any part of our carbon "chains".

These groups are:

The ALDEHYDE	$-CHO$
The KETONE	$>CO$
The ETHER	$-O-$
The AMINO	$-NH_2$

The simplest compounds involving these groups are:

FORMALDEHYDE	H-CHO	This material is a gas, but normally sold as a concentrated solution. It is a powerful germicide, and is used for preserving organic materials (such as biological specimens) for prolonged periods. Since the compound itself is fairly poisonous, it cannot be used as a food preservative. Formaldehyde was used also in making one of the earliest kinds of plastic materials.
DIMETHYL KETONE (called "Acetone")	 $CH_3-\overset{\overset{O}{\|}}{C}-CH_3$	This is a liquid, and one of the products from the destructive distillation of wood. It is used widely as a solvent, lacquer thinner, and in paint removers. Also it is a useful reaction solvent in organic chemistry. You have become acquainted already with this material in your chapter on Chemistry in the Forest.
DIMETHYL ETHER (called "Ether")	CH_3-O-CH_3	We are much more familiar with another member of the ether family, namely DIETHYL ETHER, or:
	$C_2H_5-O-C_2H_5$	This is the compound once very widely used as an anaesthetic. It is still used for that purpose, but manv other compounds have invaded the field in recent years. This is a "general" anaesthetic which puts the individual to sleep. "Local" anaesthetics act in a limited area only, and are used widely in dentistry and for minor surgery.
METHYL AMINE	CH_3-NH_2	Note that this compound can be looked upon as an ammonia molecule (NH_3) in which one of the hydrogen atoms has been replaced by a METHYL group (the CH_3 group). Similarly, we can replace one, two, or even all three of the hydrogens in this manner. Other groups besides the methyl group can be used.

As you might expect, the simple amines are basic, and in fact resemble ammonia very closely. (They even smell very much like ammonia.) They thus can undergo neutralization reactions with an acid.

Earlier in this chapter you learned that the long-chain organic acids (such as Oleic Acid) can react with metal hydroxides to give "Soaps". Similarly, long-chain (or short-chain) fatty acids can react also with amines in a neutralization reaction. In this case, however, since there is no metal ion involved, both parts of the molecule are soluble in organic solvents.

Such compounds form a special class of "soaps" which, due to their unusual solubility in organic solvents, are used by dry-cleaners. The dry-cleaning process "washes" your better clothing in organic solvents (sometimes Carbon Tetrachloride) and the use of a small amount of such "dry-cleaner's soap" helps to lower surface tension and remove imbedded dirt from the fabric.

There is another interesting usage of organic amines. Since (like ammonia) they are fairly volatile and can neutralize organic acids, they are used to form a colloidal "solution" of various waxes in water. Applied to your car, the waxes can be polished to a beautiful luster. But in addition, when the volatile amine evaporates into the air, the coating left behind is then waterproof since the amine "soap" was responsible originally for its colloidal behavior.

ESTERS: It has been mentioned that in organic chemistry alcohols are equivalent to the inorganic "bases". Thus, it should be possible for alcohols to react with organic acids in a typical "neutralization" reaction.

This type of reaction does take place, but instead of a metal salt being produced, the reaction product is called an "ester". Water also is a reaction product, just as with inorganic neutralization reactions.

To take the simplest possible case, we start with Formic Acid ($HCOOH$) and Methyl Alcohol (CH_3OH):

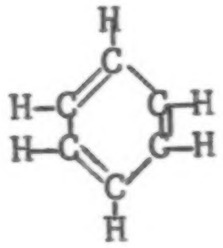
METHYL FORMATE $HCOOH + CH_3OH \dashrightarrow H_2O + HCOOCH_3$
(an ESTER)

Many of the esters have pleasant smelling odors and are used as synthetic fruit flavors.

Besides forming together in straight or branched chains, carbon compounds are known which can be proven to exist in a "ring" type of structure. This is somewhat like a snake that has rolled in a circle and swallowed its own tail. Ring compounds (also called "cyclic" compounds) usually have very distinctive odors. Thus, this class of compounds are called the "aromatic" organic compounds.

In general, the "aromatic" (cyclic) organic compounds are MUCH MORE POISONOUS than those having straight chains or chains which are branched.

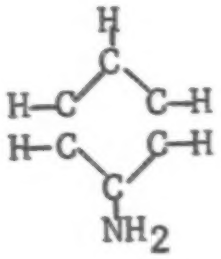
The simplest ring compound, and the first member of its particular series, is called Benzene. The empirical formula is C_6H_6, but the structural formula is written:



Benzene itself is used widely as a reaction solvent for organic reactions. Like most of the other aromatics, rarely is it used directly by the general public due to its high toxicity.

As with the straight-chain or branched-chain compounds, other atoms or groups (such as carboxyl, aldehyde, amino, etc.) can be substituted on the ring compounds also.

To give you just one such example, the combination of an Amino group on the Benzene ring produces a compound called "Analine". The structure of Analine is:



Analine

This compound, while very toxic, is also extremely useful in a great variety of organic processes and reactions. Among other things, it is the starting point for most of the beautiful "Analine Dyes" for coloring fabrics, and many other useful products.

The above classifications, groups, and typical compounds serve as a brief introduction to a very complex subject. We shall extend this somewhat in the next chapter, dealing with food and nutrition. However, now you will be better prepared to deal with the topics of the next chapter.

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on the page briefly the important points of the preceding chapter:

CHAPTER 29--YOU ARE WHAT YOU EAT--OR ARE YOU?

The queen bee, fed and cared for in a special manner, lends some truth to the first part of the statement above. Apparently, in her case, the special nutriments are required for her to develop into her position and status. Recent research on rats (which probably will be extended to human beings) tends to show strongly that MENTAL environment plays a VERY large part in brain size and development, and in psychological behavior. This is true regardless of the amount and type of food given. Hence the question raised in the latter part of this chapter title.

Be that as it may, proper nutrition certainly does play a large and fairly important role in our everyday lives. And for a world which already for generations has been living on the brink of starvation in many areas, the role of food will be one of increasing importance in the future.

Just a few years ago, the United States was blessed with large excesses of basic foods, but this situation no longer is true. What is worse, sharing this surplus with others may have helped only to compound an increasingly sharp problem. It has proved to be just a temporary relief.

The chemist has helped tremendously in the world's search for more food production. But there is only so much land available for growing food. Therefore, he is turning his attention to the sea as a future large potential source. Presently he has two items of interest to offer: 1. whole fish meal, which as the name implies is made from the entire fish, and is certainly nutritious if not appetizing; and 2. so-called single-cell protein, which can be grown on petroleum waste products. Again nutritious, but hardly in the same class with steak and potatoes.

Well, let us look at the chemistry of foods. Foods perform two functions in the body: 1. they provide material for body growth and repair; and 2. they provide energy for mechanical activity and for maintaining body temperature. Since animal bodies are composed largely of compounds containing carbon, hydrogen, oxygen, and nitrogen, it is natural that the bulk of our foods would have to contain these same elements also.

There are some other elements required in smaller amounts. These include calcium, phosphorus, iron, sulfur, sodium, magnesium, chlorine, and manganese.

This does not mean that you can get the needed amount of iron for your system by chewing on a nail. In every case, the food sources must be of such a nature that the body can digest and use the elements or compounds present.

In general, all nutritional material falls into one of the following four broad classes: 1. fat, 2. protein, 3. carbohydrate, and 4. mineral matter. Usually, a given food may contain more than one of these classes of materials, or even all four.

Water, while very necessary to the body, does not supply energy nor is it digested, so we do not consider it a food ordinarily. However, it plays an important part in the body in providing a solvent for digestive processes, as the base for body fluids, and for cell construction. The human body is about 70% water which is obtained partly from drinking water and partly from foods (mostly vegetables).

FATS: Fats and oils contain carbon, hydrogen, and oxygen. Most of the fats and oils are long-chain molecules. Like the simple hydrocarbons which we burn as fuel in our homes, the fats and oils produce heat and energy for our bodies.

When we eat more of this type of food than we can immediately use, the body has the ability to "store" the extra surplus. These reserves can be withdrawn for use at some future time of need.

Meat, fish, and poultry include fats, and so does butter, cheese, and egg yolk. And while most vegetables are not considered large sources of fats, this picture has changed considerably in the last few years. Olives, corn, coconut, cottonseed, peanuts, and soybeans have large percentages of oil, and all have become commercial sources of this type of food.

CARBOHYDRATES: Carbohydrates also include the elements carbon, hydrogen, and oxygen, but in different structural relation than the fats. The sugars and starches belong to this class of materials which are used primarily by the body as fuel foods. Unlike fats, excess surpluses of carbohydrates cannot be stored directly by the body, but the body can convert these materials to fats and store them as such.

Potatoes, rice, cereals, beans, and peas all contain a high percentage of starch. The sugars we eat are derived mainly from tree syrups, from the sugar beet or from various fruits (especially dates, figs, grapes, raisins, and bananas).

PROTEINS: The main function of this class of food is the building and repairing of body tissue which cannot be done by

5

either the fats or carbohydrates. To a limited extent, the proteins can serve also as fuel foods, but this is not their main function.

Lean meat, fish, poultry, egg white, and cheese are the main sources of protein for the diet. But here again beans and peas, as well as certain grains, contain considerable amounts.

We have mentioned already that proteins are used industrially as binders, thickening agents, and adhesives. Here again, the trend has been away from animal products into the vegetable or dairy fields. Furniture glue made of horse and cattle hooves has given way to casein protein derived from milk, or to soybean protein.

MINERALS: The presence of small amounts of mineral materials (inorganic chemicals) is necessary in our food. Besides being essential to the formation of bones, teeth, and protoplasm, minerals are necessary to digestive processes. The salt you eat is changed to hydrochloric acid, which is one of the components of digestive fluid.

Most of the fruits and vegetables contain minerals, but lettuce, tomatoes, celery, grapes, raisins, oranges, spinach, and cabbage are particularly good sources of minerals for the body.

Besides the necessity for chloride ion mentioned, very small amounts of iodide ion also seem to be necessary to the human body. A deficiency of this substance may cause the condition known as goiter. Iodides are found in some sea creatures, and the needed amount is supplied usually by eating salt water fish. However, people living far inland may have little opportunity or inclination for this type of food. In recent years, potential lack has been corrected by the sale of "iodized" salt.

Recent research tends to show that the presence of small amounts of fluoride ion may be desirable to reduce tooth cavities. Due to the large number of factors involved, the situation probably is NOT resolved completely. Yet many communities have added fluorides to their supply of drinking water.

Here is an example of the need for an informed and alert citizenship in making decisions that can affect many people.

Fluoride is a very poisonous material. In toothpastes usually the fluoride is supplied in the form of a very insoluble compound, so that the effective concentration of soluble fluoride ion is very small. In treating water supplies, they severely limit the amount of fluoride ions. Yet, in view of its very toxic nature, one can wonder whether enough long-term research has been done on this problem to insure that the treatment is doing more good than harm.

In making such decisions, one must keep in mind that commercial firms who make and sell the chemical and the equipment to "meter" it into water systems have an individual "axe" to grind, and may tend to promote things which have been studied insufficiently or which are borderline in research results.

VITAMINS: Vitamins are complex organic substances which are necessary in small amount for the human body. Probably they act as catalysts for certain reactions.

Lack of certain vitamins in the diet may result in so-called "deficiency diseases". Such diseases usually are cured rapidly when the lack is remedied by feeding the proper vitamin. Scurvy, pellagra, and beri-beri are diseases caused by vitamin deficiencies.

Without going into great detail, milk, butter, eggs, cheese, cereals, meat, and green vegetables are good sources for Vitamins A, B (a whole group), E, and K. The citrus fruits (limes, lemons, oranges, grapefruits) are good sources for Vitamin C.

From the above food lists, you can see that a varied diet, and food in reasonable amounts, should be able to supply a person with all the needed vitamins. This is usually the case. Conversely, however, a person exposed to an extremely limited diet by choice or necessity, may require extra vitamins.

In general, the intake of excess vitamins does not appear to do any harm. Based on this, vitamin manufacturers have for years tried to push their products by "fear" campaigns. While it is important that a person receive the needful amount of vitamins, in many cases there is no real need to supplement the diet by taking vitamin pills.

HORMONES: There is another class of organic substances which are necessary to human life and well-being called the "hormones". They are not foods in the true sense of the word because they are products normally manufactured by the body itself for its own uses. Their influence on normal body chemistry, and the physical and mental effects produced, are very profound. With advancing age, the body itself produces less and less of these substances. Accordingly, it may suffer from physical and mental disturbances due to a lack of one or more of the various types of hormones.

The advance of chemistry in the past forty years has resulted in learning more about the structure and function of the various kinds of hormones, and even in their synthetic commercial production. Thus, with advancing age, men and women can (under a physician's care) learn to supplement their diet with synthetic hormones to replace their own failing supplies with outside sources.

This field of applied chemistry is still fairly new, but with a world trying to push back the barriers of man's natural age more and more, it is taking an increasingly important role.

In summary, yes, we are to a certain extent what we eat. A varied diet, in reasonable amount, seems to be the best approach to meeting the body's needs for proper nutritional requirements. Especially for those nations with inadequate food supplies, an effort to bridge these nations' petty differences is needed so that they can get to work on the fundamental problem of feeding their populations.

On this page write five good questions on the preceding material that could be used as examination or quiz questions. Ask proper questions on important points in the chapter, and word them carefully so that they read correctly. Do NOT ask discussion type questions.

In your own words outline on this page briefly the important points of the preceding chapter:

TABLE 1

SYMBOLS OF COMMON ELEMENTS WITH APPROXIMATE RELATIVE ATOMIC WEIGHTS

Name	Symbol	Relative Atomic Wt.
Aluminum	Al	27
Arsenic	As	75
Bismuth	Bi	208
Boron	B	11
Bromine	Br	80
Cadmium	Cd	112.4
Calcium	Ca	40
Carbon	C	12
Chlorine	Cl	35.5
Copper	Cu	63.6
Fluorine	F	19
Gold	Au	197
Helium	He	4
Hydrogen	H	1
Iodine	I	127
Iron	Fe	55.8
Lead	Pb	207
Magnesium	Mg	24.3
Mercury	Hg	200.6
Nitrogen	N	14
Oxygen	O	16
Phosphorus	P	31
Potassium	K	39
Silicon	Si	28.3
Silver	Ag	107.9
Sodium	Na	23
Sulphur	S	32
Tin	Sn	118.7
Zinc	Zn	65.4

Lab Unit	Title	Page
1	1. Introduction	L1
	2. Lecture by Instructor on Lab Safety	L1
	3. Learn the Names of Each Piece of Lab Equipment	L1
2	The Role of Chemistry in Today's World	L2
3	Measurement--The Metric System	L3
4	Physical Properties--Color, Odor, Taste, Malleability	L5
5	Physical Properties--Density	L8
6	Physical Properties--Melting Point	L10
7	Physical Properties--Viscosity	L11
8	Physical Properties--Surface Tension	L13
9	Chemical Properties of the Element Chlorine	L16
10	Change of State: Melting/Boiling Curve	L20
11	Chemical Change--Synthesis	L22
12	Chemical Change--Decomposition	L25
13	Percentage of Oxygen in Air	L28
14	Size of An Oleic Acid Molecule	L30
15	Boyle's Law	L34

LAB UNIT #2: THE ROLE OF CHEMISTRY IN TODAY'S WORLD

Obtain some big city newspapers and turn to the WANT ADS. Make an individual list of twenty different kinds of jobs which are offered there. Then, opposite each one put down your opinion as to whether or not a chemical training or background would be helpful for that job.

Hold a GROUP DISCUSSION, after you have finished the above, with your instructor guiding the discussion. Notice the salaries attached to the more highly skilled positions.

Now, turn to the front page and the page or two following it. How many articles are there in which chemistry is directly or indirectly involved? Make a list of ten such articles and the role of chemistry in each.

Again, discuss each article as a group with your instructor leading the discussion. From the front page articles do you think that we need faster progress in social science, or in physical science?

LAB UNIT #1:
1. INTRODUCTION
2. LECTURE BY INSTRUCTOR ON LAB SAFETY
3. LEARN THE NAMES OF EACH PIECE OF LAB EQUIPMENT

LAB SAFETY: A laboratory can be a dangerous place, but the home is also full of hazards. True safety is being aware of possible hazards, and taking them properly into account. True safety also means using the right equipment or tools for the right job, and using them in a proper, safe, manner.

Your laboratory experience will be more enjoyable if you can avoid cut or burned fingers, acid holes in your clothes, or other kinds of hurt and injury. KNOW WHAT YOU ARE TRYING TO DO, AND DO IT RIGHT.

Be especially careful of other students around you. DON'T spatter them with dangerous chemicals. DON'T point boiling test tubes at them. DON'T run around with sharp glass tubing. DON'T BOTHER THEM; and DON'T engage in horseplay. They have their own work to do, just as you do.

If you smell something, do it with CAUTION. DON'T taste anything unless your directions tell you it is safe. DON'T EAT while in the lab.

Always keep your equipment neat and orderly. You can wash it while watching an experiment.

Keep neat and orderly records. This is part of the benefits you can get from a laboratory course. READ the experiment before you come to class. You will get a lot more out of the lesson.

FINISH what you start. If the period is too short, run over into the next lab period, or come in (by arrangement with your instructor) at some other time.

DON'T just go through the motions and quickly fill in the blanks. People have devoted their lives to science so that you might have a better understanding of the world you live in. THINK about your results and what other possible application they might have in your everyday life.

LOCATE EVERY SAFETY DEVICE, SUCH AS FIRE EXTINGUISHER, FIRE BLANKET, OR SAFETY SHOWER. Your instructor will explain their use, but you need to know just where they are.

IF ANY CHEMICALS GET IN YOUR EYE, WASH IT IMMEDIATELY WITH WATER. Then ask your instructor for further procedures or treatment.

LAB UNIT #3: MEASUREMENT--THE METRIC SYSTEM

1. Get a meter stick and become familiar with its markings. Lay it alongside a regular foot ruler and compare the two. Figure out how you can make a numerical comparison between the two systems. Read the necessary numbers on the two rulers, and do the arithmetic. What is your answer? ONE inch = ______________ centimeters

2. Using the meter stick, measure the inside of your laboratory drawer. Record neatly the length, width, and depth. What is the volume of your drawer? ____________ cubic centimeters

How many significant figures should you have used in reporting the volume figure? ____________

3. Take one of your beakers and measure its height ________ cms, and diameter, ____________ cms.

Figure out the volume of the beaker, in cubic centimeters, from your measurements, using the formula: $V = \pi r^2 h$ Volume ________ cms^3

Now, using the graduated cylinder in your desk equipment (careful, they can break) carefully fill the beaker to the top. How much water did it take? _____ ml

How do your two measurements compare? _________ by meter stick, ____________ by cylinder

Which measurement do you think was the most accurate? __________

Why? ____

4. Take ten washers, all the same size, and weigh them individually (one at a time) on your lab balance. Record the weights in the following spaces:

_____ grams _____ grams _____ grams _____ grams

_____ grams _____ grams _____ grams

_____ grams _____ grams _____ grams Average: _____ grams

Assuming that you will not get exactly the same weight for each washer, compute the average weight. You obtain this by adding up the total weight and dividing this by ten.

If you were in the hardware business and going to ship washers by freight or truck, would you weigh just one washer to determine your cost, or take an average? ________ WHY?

____

5. Take a marble, or ball bearing, and roll it across the floor between two chalk marks about 8 feet apart. Obtain a stop watch and become familiar with its operation and how to read it. Now, roll the marble across the floor ten times, and time it each time as it rolls between the two chalk marks. Record the time:

_____ seconds _____ seconds _____ seconds _____ seconds

_____ seconds _____ seconds _____ seconds RANGE: _____ seconds

_____ seconds _____ seconds _____ seconds AVERAGE: ___ seconds

WHY are the times different in each case? __________________

____

6. At this time you are going to drop the marble from your hand held about the height of your head. Hold the marble at the same height each time, and time it from the moment you open your hand to the time it reaches the floor:

_____ seconds _____ seconds _____ seconds _____ seconds

_____ seconds _____ seconds _____ seconds RANGE: _____ seconds

_____ seconds _____ seconds _____ seconds AVERAGE: ___ seconds

7. Compare the RANGE (the instructor will explain this term) for Experiments #5 and #6. Even though the average time will probably be shorter for Experiment #6, the range is probably less. WHY? ____

8. Light up your Bunsen Burner and experiment with it to obtain different kinds of flames. Discover how to adjust it. If time permits, take a short piece of glass tubing and put a bend in it.

LAB UNIT #4: PHYSICAL PROPERTIES--COLOR, ODOR, TASTE, MALLEABILITY

There are many physical properties which could be used to help describe different materials. Some of these are listed in your textbook. However, we cannot study all of them, but will take up a few which are most useful to us and easiest to measure.

COLOR: Color is a very useful physical property if we restrict its usage to the basic, natural color of a material. By this means alone, you could easily tell the difference between a piece of wood and a piece of iron metal, for example.

Find the following materials in the laboratory and examine each one for its color:

Material	Color	Material	Color
SULFUR		WATER	
LEAD		ALCOHOL	
IRON		ALUMINUM	
IODINE		COBALT NITRATE	
WOOD		ACETONE	
COPPER		SILVER	
COPPER SULFATE		GOLD	
SILVER NITRATE			

Would you be able to tell whether a piece of metal might be silver, lead, iron, copper, or gold just from its color? ____

Would you be able to tell whether a liquid might be water, acetone, or alcohol just from its color? ________________

You can see from the above that color is a very useful property, but by color alone we cannot distinguish between all different kinds of materials.

ODOR: Find the following materials in the laboratory, and (CAUTION) smell them: (DESCRIBE the smell as well as you can)

Material	Odor	Odor	Odor
COPPER METAL			
SULFUR			
WATER			
HYDROCHLORIC ACID (Caution)			
ACETONE (Caution)			
AMMONIUM HYDROXIDE (Very carefully)			
ALUMINUM METAL			
SUGAR			

Material	Odor	Odor	Odor
SODIUM CHLORIDE (Salt)			
ALCOHOL			
ACETIC ACID (Caution)			

Could you tell the difference between water, alcohol, and acetone just by odor alone? ____________________

Could you tell the difference by odor alone between copper metal, sulfur, or aluminum metal? ____________________

WHY do you suppose that some materials (like acetone) HAVE an odor, and others (like clean copper metal) do NOT have any odor? ____
____

So again we see that odor can be a useful physical property, but it cannot serve by itself to identify every different kind of material.

When we can smell a certain kind of material, does this mean that very small "pieces" of this material are actually in the air? ____________________

TASTE: Due to the danger of tasting harmful chemicals, this property must be evaluated with GREAT CAUTION. Follow directions carefully.

Ammonium Hydroxide: Take ONE DROP of concentrated ammonium hydroxide and add it to 10 ml of water in a clean beaker. Stir the solution. Take a sip of the solution and describe the taste: ____________________

Acetic Acid: Take ONE DROP of concentrated glacial acetic acid, and add it to 10 ml of water in a clean beaker. Stir the solution. Take a sip of the solution and describe the taste: ____________________

Rinse your mouth out with plain water right after you taste these materials.

The two materials you have just tasted are typical of all "acids" and "bases". You will learn later what these two terms mean.

Sulfur: Take a small pinch of powdered sulfur and taste it. Results? ____________________

Taste is a useful physical property, but must be used with caution in chemistry because many of the materials are poisonous or damaging to your teeth or skin.

MALLEABILITY: Obtain small pieces of copper, iron, and sulfur. Place them on a metal plate, or on a brick or cement block and hit them with a hammer.

Material	Malleability
COPPER	
IRON	
SULFUR	

You will find that some materials will "flatten" under a hammer. Some will break. Some will resist the blow better. Some metals are especially useful for their ability to be flattened rather than breaking.

LAB UNIT #5: PHYSICAL PROPERTIES--DENSITY

DENSITY: Density is one of our most useful physical properties. Density is the weight per unit volume of a material. It applies to gases, liquids, and solids. In this unit we shall measure the density of some common liquids and solids.

To measure the density of a material, you must take a certain amount of it and measure two things: (1) the weight of that amount of material, and (2) the volume it occupies.

It is easy enough to measure weight. Put the object or material on a laboratory balance, and add or subtract weights to equal the weight of the object.

YOUR INSTRUCTOR WILL SHOW YOU HOW TO USE THE BALANCE.

There are several ways of measuring volume.

If the object is small enough, you can find its volume by using your "graduated cylinder". Fill your cylinder partly full of water. Carefully READ the volume. Write it down, of course. (Volume #1)

Then drop the object into the cylinder. This will make the water level RISE by an amount equal to the volume of the object. Read the new water level, and write it down. (Volume #2)

The second volume reading, minus the first volume reading, will give the volume of the object.

Then to get the DENSITY of the object, divide its weight by its volume:

DENSITY = weight/volume

If an object were to float on the water, obviously you could not find its volume by this method. You could, however, use acetone, or kerosene, instead of water in your graduated cylinder.

To measure the density of liquids, just weigh your empty graduated cylinder. Put a few ml of the liquid in it, and re-weigh. The difference in weights gives you the weight of liquid taken, and the volume can be read directly from the markings on the cylinder.

USING THE ABOVE METHODS, measure the density of the following:

Material	Weight of Material Taken	Volume of Material Taken	Density = Wt./Vol.
WATER			grams/ml
KEROSENE			
PARAFFIN			
PIECE OF ROCK			
MINERAL ORE			
LEAD			
ALUMINUM			
COPPER			
GLASS			
IRON			

Take a piece of paraffin, a piece of glass, and a piece of iron in your hands. Do you think that you could guess at their densities without making a measurement? ______________

In some outside reference, or from your instructor, find out the known accepted values for the densities of the above materials. Compare the accepted values with yours in the table below:

Material	Experimental Value	Accepted Value	Percent Error
WATER			
KEROSENE			
PARAFFIN			
PIECE OF ROCK		UNKNOWN	
MINERAL ORE		UNKNOWN	
LEAD METAL			
ALUMINUM			
COPPER			
GLASS			
IRON			

LAB UNIT #6: PHYSICAL PROPERTIES--MELTING POINT

MELTING POINT (also Freezing Point; they are the same):

Take a small test tube and fill it full of small pieces of paraffin. Place the test tube in a beaker of water and heat the water with your Bunsen Burner.

When it looks like the paraffin is beginning to melt, put your thermometer into the paraffin and mix it up. Make a note of the temperature: __________° C.

AFTER the parafiin is completely melted and liquefied, turn off your burner and let it cool down slowly. Every few seconds mix it up a little bit with your thermometer. Finally, some paraffin will start to solidify. At this point read the thermometer again: ________° C.

If you have worked pretty carefully, the two readings will be fairly close together. Take an average: ________° C. This is your experimental value for the melting point of paraffin.

The usual "accepted" value for the melting point of paraffin is 55° C. However, paraffin itself is a mixture, rather than a pure material. Therefore, your value may not agree too well with the accepted value because the true value will depend upon what company it came from and what mixture they sell as "paraffin".

The melting points of pure materials are quite different, and this is a very useful tool in identifying chemical materials.

What is the melting point of water? _____________° C.

LAB UNIT #7: PHYSICAL PROPERTIES--VISCOSITY

VISCOSITY: All liquids show a "resistance to flow" which is called viscosity. Even water, which flows quite rapidly, has a certain measurable viscosity. Gases also show viscosity effects.

Viscosity is a very useful physical property, especially for the control of commercial manufacturing and packaging operations. The table syrup you put on your pancakes in the morning is controlled in its manufacture by viscosity, rather than by chemical analysis, because viscosity can be measured quickly and easily.

As auto engines get older, the bearings and other moving parts get slightly worn. To prevent excessive loss of engine oil, we use oils of higher viscosity in older engines.

If you are a construction engineer, you might have to pump cement "slurries" or "muds", or mixtures of sand and water or other liquids containing suspended materials. You would have to take the higher viscosity of these liquids into account in planning your pumping equipment because it would take larger pumps and greater power requirements to pump these materials than it would take for water.

Viscosity, surface tension, and density are three properties that would appear to have some relation to each other for the same liquid. Whether this is true or not, we will investigate a little further in this experiment.

Your instructor will put out several oils of different viscosity values, including one of "unknown" value. For each oil, one at a time, measure its density (using your graduated cylinder for this). Then fill your graduated cylinder almost to the top with one of the oils, and drop a BB shot into it. With a stop watch you will measure the exact time it takes for the BB to drop between the ZERO MARK and the 50 ML MARK in the graduated cylinder. Record this time. Then REPEAT the measurement with another BB. Record the second measurement, and if they differ, take the average between the two values.

Do this for EACH oil, recording your data here:

	Known Visc. Value	Exptl. Density Value	Time to Drop (1)	Time to Drop (2)	Average Time
OIL #1					
OIL #2					
OIL #3					
OIL #4					

Now, on the following piece of graph paper, plot two experimental curves:

(1) The "Known Viscosity Value" (expressed as S.A.E. values for engine oils) plotted against your "Experimental Density Values".

(2) The "Known Viscosity Value" (again expressed as S.A.E. values) plotted against your "Average Drop Time".

To plot properly, you will have to decide how to space your values along the two coordinates. Then draw lines for the two coordinates, and then enter points for the various values involved above.

DO THIS NEATLY. Finally, connect your experimental points by a smooth curve which will best fit the points.

From your graphed data you should be able to answer the following questions:

(1) Does Viscosity change with the Density of a material?

(2) What is the Viscosity of the UNKNOWN OIL: S.A.E. # _____

(3) Was it of any practical value to take TWO readings of the DROP TIME for the BB shot going through the oil, or would ONE reading have done just as well? __________

WHY should you take TWO readings any how? __________

____

Find out from outside reading (or ask somebody who should know the right answer) whether there is any relation between surface tension and viscosity.

With your CLEAN, DRY graduated cylinder, take the DROP TIME of a BB shot through ACETONE: __________ seconds.

What can you say about the viscosity of acetone relative to oils? ____

LAB UNIT #8: PHYSICAL PROPERTIES--SURFACE TENSION

SURFACE TENSION: Molecules at the surface of a liquid are subject to an UNEVEN distribution of molecular forces.
WHY? ____
____

This uneven distribution of forces at a liquid surface (and also at the interface between two liquids which do not mix) results in a force called "surface tension". This force is very small, but it is measurable, and plays a very important part in daily life.

A duck or swan can float high on the surface of a pond with most of its body out of the yater. Yet the actual density of the animal and of the water, like your own, is very close to that of water itself, but the duck or swan is surrounded by a fluffly covering of feathers which is water-repellant. Thus, these birds are supported mostly by these tiny, invisible forces of "surface tension".

Water has a high surface tension value compared with most other liquids. This also means that instead of "wetting" other materials, it would prefer to draw up into "droplets", and not really touch them. In order to come into really close contact with other materials, we would have to lower the force which prevents this, in other words, lower the surface tension.

Have you ever tried to wash greasy dirt off your hands just by water alone? It doesn't work very well, does it? This is because the high surface tension of the water prevents it from getting into close contact with the dirt. Soaps, or detergents, are materials which lower the surface tension of water, thus permitting the water to get "all around" the dirt and carry it away.

Surface tension can be measured in several different ways. However, always remember that the force is very small, and you won't be able to see its effects unless you work very slowly and carefully, and keep everything very clean.

1. Take a piece of capillary tubing (this means it has a very small hole through it) about 4" long. Clean it by pouring some nitric acid through it (CAUTION: DON'T GET IT ON YOUR SKIN, EYES, OR CLOTHING), and then rinse it under the water faucet VERY, VERY WELL.

Rig up some way of clamping the piece of capillary tubing in an UPRIGHT position with the bottom end dipping into a CLEAN watch glass.

Get your head down on a level with the watch glass and add a few ml of pure water to the watch glass. You will find that the water will RISE IN THE CAPILLARY TUBE ABOVE THE LEVEL OF THE WATER IN THE WATCH GLASS. This is due to surface tension.

With a ruler measure as carefully as possible the height of water in the capillary tube above its height on the watch glass. ______________ cms.

Take the watch glass away so that the capillary tube drains, and set up the apparatus again, but this time use water with a little bit of detergent in it.

Put your head down level with the tube again and re-measure the height: ______________ cms.

Since the surface tension is directly proportional to the height of the liquid in the tube, what has happened to the surface tension when you added detergent? ________________

Now remove the tube and RINSE IT VERY WELL under running water.

Set the tube up again vertically, but this time add some ALCOHOL to the watch glass. Measure the height of the liquid: ______________ cms.

What can you say about the surface tension of alcohol compared with that of water? ______________________

How about alcohol compared with that of detergent plus water? ____

2. Take a CLEAN, DRY NEEDLE. Carefully lay it down on the calm surface of water in your plastic trough or gas collecting tank.

Does it float? _________ Is it floating because steel is less dense than water? What is the relative density of water? ____________ Of steel? _____________

With your needle still floating, take a CLEAN glass rod and gently touch it to the water, several inches from the needle. Does anything happen? _________________

With your needle still floating, put a tiny drop of liquid detergent on your glass rod and touch it again to the water surface, several inches away from the needle. What happens? ____

What do you suppose would happen to a duck or swan if you put detergent into his pond? ___________________________

3. Take a small piece of cloth and pour a few ml of water onto the middle of it while you hold it over a beaker.

Does any water come through the cloth? ____________________

Now, take a solution of paraffin wax in solvent (CAUTION: FIRE HAZARD), and saturate your cloth with this solution. Wait till it dries.

When the cloth is dry, put some more water on it. Does it come through the cloth? ____________________

Now, put some detergent water on top of the cloth. What happens this time? ________________

What would the world be like if we had volatile detergents? Which would come down with the rain? Would things rust more?

LAB UNIT #9: CHEMICAL PROPERTIES OF THE ELEMENT CHLORINE

In this lab unit we want to find out how the chemist goes about observing chemical properties. We have to study one particular material, and it is simplest to take an element for this study.

The element CHLORINE will be prepared and studied in this lesson. It is a very common and useful element, with some interesting properties. However, it has certain drawbacks also. Chlorine was the POISON GAS used in World War I, so of course you don't want to breathe it in large amounts.

When you make it, make it UNDER THE HOOD. This is a device used by chemists to remove disagreeable gases and odors so that they don't get too much of them. In its simplest form, it is a box with a fan. The fan sucks the gas outside the room.

The element chlorine is a member of the "HALOGEN" family. It can be made by heating together a powdered solid called manganese dioxide, and a liquid called Concentrated Hydrochloric Acid.

When you heat the two above materials together, they will give off the gaseous element chlorine. We will want to collect the gas in some of our small gas collection bottles.

1. DRAW A DIAGRAM of an apparatus which will enable you to perform the above experiment:

In designing your experimental setup, you will need to know that:

A. You will need a container for your "reactants" that will:

(1) Hold about 5 grams of MnO_2 and 20 ml of Conc. HCl

(2) Stand heating with a Bunsen Burner

(3) Give you some way of leading the gas formed (Chlorine) into your collection bottles

B. Chlorine gas is partly soluble in water, and is heavier than air. When you do get the gas, how will you get it into your collection bottles?

AFTER YOU HAVE HAD A CHANCE TO THINK OVER AN EXPERIMENTAL SETUP, HAVE A GROUP DISCUSSION TO SEE WHETHER EVERYBODY AGREES ON A REASONABLE WAY OF PERFORMING THE EXPERIMENT. YOUR TEACHER WILL LEAD THIS.

2. Get together all of the equipment you will need to generate and collect chlorine gas. Put the apparatus together. Get the bottles ready to collect the chlorine, and some means for closing them. Weigh out your chemicals for the reaction.

PUT EVERYTHING UNDER THE HOOD.

If you do not have a hood, then several students had better work together on one apparatus, AND TAKE CARE NOT TO BREATHE TOO MUCH CHLORINE.

Gently heat your reaction vessel, and start generating chlorine. Collect at least four bottles of gas. One bottle should have a few ml of water in it, but the rest should be dry. Cover the bottles so the chlorine does not escape. Let your apparatus cool before you take it apart and wash it.

3. Try the following experiments and record your results:

A. Put a piece of blue litmus paper and a piece of colored cloth into the bottle of gas containing some water. Does anything happen right away? ______________________________

Keep the bottle closed, and look at it about 10 minutes later.

Has any other change occurred? ___________________________

B. Take a small amount of powdered antimony metal and sprinkle it into a bottle of chlorine. What happens? _____

____

Repeat this. Afterwards, feel the bottom of the bottle:

Observation: ____________________________________

Is the reaction of chlorine with antimony connected with any change of energy? ____________________________

C. Warm a few ml of Turpentine (CAUTION: INFLAMMABLE) and put it on a piece of filter paper. Immediately put the paper into a bottle of chlorine gas. What happens: __________

____

D. In your own words, try to describe the odor and color of chlorine so that another person could identify the gas from your dscription:

ODOR: ____

COLOR: ____

Are these chemical or physical properties? ________________

If you can get another bottle of chlorine from your experiment, try to POUR the gas from one bottle to another. HOLD IT IN FRONT OF A SHEET OF WHITE PAPER SO YOU CAN SEE THE GAS WHILE YOU POUR.

From this, is chlorine heavier or lighter than air? __________

REVIEW: In this experiment you learned the following things:

1. How to prepare the element chlorine (a gas).

2. A few physical properties of chlorine: color, odor, relative density compared with air, partly soluble in water.

3. A few chemical properties:

A. That it gives an acid solution when dissolved in water

B. That it can bleach natural dyes (on the litmus paper) and synthetic dyes (on the colored cloth)

C. That chlorine will react at room temperature with certain metals such as antimony

D. That the reaction of chlorine with antimony gives off light and heat. Therefore, energy is released by the reaction.

E. That the product of reaction of chlorine and antimony is a whitish solid (the name of this material is antimony chloride)

F. That chlorine is so reactive that it will instantly react with turpentine

In this experiment, when you first put the manganese dioxide and hydrochloric acid together before you applied heat, did you get much chlorine generated? ______________________

What heppened to the reaction when you began to heat the two chemicals together? ______________________

Do you think, as a general rule, that most reactions will go faster at higher temperatures? ______________________

If you wanted to collect a gas that did not dissolve in water, how would you do it? ______________________

____

LAB UNIT #10: CHANGE OF STATE: MELTING/BOILING CURVE

We already know that many materials can exist in all three states of matter as a solid, liquid, or gas (vapor). We also should know by now that a change of energy is always associated with a change of state. The following experiment will demonstrate this for our familiar friend water.

1. In this experiment we are going to take some ice (preferably from a cold enough source so that it will be below 0° C when we start). We will put this into a beaker and apply a constant input of heat energy from a Bunsen Burner. We will take also temperature readings with our thermometer at one minute intervals.

This procedure will be continued until the water boils, or the thermometer does not rise any further.

The temperature readings will then be plotted on a graph against the time. Since we can assume a constant rate of energy input from the burner, the time element will also be a measure of energy input. The resulting graph should show what happens to the energy input at the freezing and boiling points. It will also show us the actual freezing and boiling temperatures of water at our particular elevation. Remember that only at sea level (or standard conditions of pressure) does water freeze at 0° C and boil at 100° C.

A. Perform the above experiment, starting with at least 100 grams of ice. Stir the ice with the thermometer to get a good reading of the ice temperature. Once you start the burner, you must CONTINUE stirring slowly but constantly until the end of the experiment.

B. Have a watch handy, or use the second hand on the clock, to take your temperature readings each minute.

C. Record your temperature readings and the time.

D. Plot the temperature against the time in minutes.

E. Connect the experimental points on your graph. The resulting curve has certain distinguishing features.

Answer the following questions:

From your curve, what is the freezing point of water at your altitude: ________________

From your curve, what is the boiling point of water at your altitude: __________________

Are there any "breaks" in the direction of the temperature/time curve? ______________

If any, where do such "breaks" occur? ______________________

What does the "break" mean in terms of energy input into the system? ____

____

Then what can you say regarding energy changes and change of state? ____

2. Take an old test tube and fill it with pieces of paraffin. Place it in a beaker of boiling water until it melts, and for a while longer.

Insert a thermometer and read the temperature. Write it down. Watch the clock and read the temperature once each minute. Record your readings.

Graph your results, by plotting time against your temperature readings.

Connect the experimental data points by a smooth curve.

Answer the following questions:

From your experimental curve, what is the freezing point of paraffin? ______________

Is there any "break" in the direction of the experimental curve? __________

If so, where does this "break" occur: _____________

What does the "break" mean in terms of energy input (or energy loss) of the system? ____

What can you say about the change in energy and change in state of paraffin: ____

____

LAB UNIT #11: CHEMICAL CHANGE--SYNTHESIS

In this lab unit we shall concern ourselves with bringing about a change in both physical and chemical properties of a material (or materials). Therefore, we shall be making a chemical change.

You have learned already that such changes involve "reaction" between definite numbers of atoms (one to one, two to one, one to three, etc.). You have also learned that atoms of each kind have a definite weight (the relative atomic weight). Thus, you can deduce and expect that reactions between elements will take place in a definite ratio by weight.

You can also expect that the properties of materials formed by a reaction will be different from the properties going into the reaction.

1. COPPER SULFIDE: Weigh out as carefully as possible 2.0 grams of copper turnings. Also weigh out 2.0 grams of powdered sulfur. Take a fairly large test tube (preferably an old one since it will probably get damaged in the experiment), and weigh it to ± 0.1 gram: ____________________

Put the sulfur into the bottom of the test tube and push the copper turnings in on top.

Now, heat the test tube strongly in a flame. (USE THE HOOD. THIS WILL MAKE STRONG FUMES OF SULFUR DIOXIDE.) Continue until you think all reaction has stopped.

Do you see any indication that something is taking place between the two elements? ___________

COOL THE TUBE down to room temperature, and weigh it again: _________________. (While the tube is cooling, you can proceed with Part 2.)

Now, the reaction of copper metal with sulfur takes place according to the equation:

$$\begin{array}{ccc} Cu + S & \dashrightarrow & CuS \\ 63.6 \quad 32.0 & --- & X \end{array}$$

The numbers underneath the symbols indicate the relative atomic weight of the elements. From the amount of copper you took, using simple ratio arithmetic, PREDICT HOW MUCH COPPER SULFIDE WOULD BE FORMED: ___________________________

Now, from the weight of the empty tube, and the weight of the tube after reaction, how much copper sulfide was actually obtained from your experiment? ___________________

Why did we ask you to use an excess of sulfur? ____________

____

Now, shake out the contents of the tube, or break the tube open and save the contents.

A. What changes in physical appearance have taken place?

____

B. Is there any visual evidence for the presence of either sulfur or copper metal? ______________________________

C. Shake a little of your reaction product (copper sulfide) with a few ml of Carbon Disulfide (DANGER-FLAMMABLE), filter, and let the liquid evaporate in air to dryness.

Is there any evidence of the element sulfur? ______________
(CAUTION: SKIN BURNS)

D. Put a little Conc. Nitric Acid on a small amount of your reaction product. Smell the result: ______________

Put a little Conc. Nitric Acid (CAUTION) on a small amount of copper turnings. Smell the result: ____________________

Is there any evidence for a change in chemical properties as a result of the reaction? ____________________________

____

2. Take about 2 grams of iron filings, and mix them intimately with about 2 grams of powdered sulfur. So far this is just a mixture. Draw a magnet through this mixture. What happens to your iron filings? ______________________________

Re-mix your sulfur and iron filings, put them in a test tube (old one preferred), and heat STRONGLY until everything gets to red heat.

Cool. Break open the tube. Examine the contents.

A. Is the reaction product (iron sulfide) attracted by a magnet? ______________

B. Is there any change in physical appearance after the reaction? ____

C. Test the reaction product with a little Conc. Hydrochloric Acid. Smell the result: ____________________

Test the original iron filings with a little Conc. Hydrochloric Acid. Smell the result: ______________________________

D. Is there any evidence for a change in chemical properties due to the reaction: ____________________

3. The two reactions in this Lab Unit build up compounds from elements. This general type of reaction is called synthesis. Today, thousands of compounds can be "synthesized"; and many of them are very important in our daily life.

LAB UNIT #12: CHEMICAL CHANGE--DECOMPOSITION

In the previous Lab Unit we learned a little bit about putting the atoms of elementary substances together to form more complex materials--"compounds". This process was called "synthesis". In this Lab Unit we learn something about the opposite reaction, where the more complex "compounds" are torn apart to their elementary materials. This latter process is called "decomposition".

Since in many cases we require elementary materials (elements) to take part in industrial reactions, the decomposition reactions are important to us in furnishing these elements from compounds that occur in nature. In this Unit we shall study two such decomposition reactions. Both are interesting, but only one is of industrial importance.

1. Decomposition of Sucrose: Sucrose (regular or common sugar) is the familiar sweet product you put in your coffee or tea. It is derived from the juice or sap of certain plants, particularly sugar cane, sugar beets, or sugar maple trees. Let us take a look at its chemical composition:

$$C_{12}H_{22}O_{11}$$

This chemical formula for the sucrose molecule tells us that it contains carbon, hydrogen and oxygen atoms. If you notice, the hydrogen atoms and oxygen atoms are in the same ratio (2:1) as in water.

Now it happens that concentrated sulfuric acid (CAUTION--SKIN BURNS) very badly wants to take up water. It is a dehydrating acid, or dehydrating agent. We can make use of this particular chemical property of sulfuric acid in the following reaction.

1. In this experiment we are going to "decompose" water by means of an electric current, using an auto battery, or a six-volt or 12-volt flashlight battery as the source of electrical energy.

When water is decomposed, two gaseous elements are liberated. Assuming that both gases are not too soluble in water, in the space below draw an apparatus which will serve to collect each gas separately (one collects on one "pole" and the other gas at the other "pole").

Since pure water is a non-electrolyte, it will NOT carry much of an electric current because it has very few "ions" in it. Therefore, we will have to add a little electrolyte to it.

Set up your battery circuit and your apparatus to collect the gases. Put a little salt (sodium chloride) or a few drops of sulfuric acid into the water to furnish ions and carry the current properly.

When your experiment has started, go ahead to Part 2 since it will take a while to collect some gas. In fact, if necessary let the experiment run for two or three hours and come back to observe it.

A. Are gases coming from both electrodes? ____________

B. What is their approximate ratio by volume? ________

C. Is the largest volume coming from the plus or minus pole of the battery? ______________________________________

D. Considering the reaction for the decomposition of water is:

$$2\ H_2O \dashrightarrow 2\ H_2 + O_2$$

which gas should come off in greatest proportion? _________

E. Which pole of the battery should the hydrogen gas come from? _____________ Which pole should the oxygen gas come from? __________________

F. Give the symbol for the hydrogen ion in solution: ______

G. Explain why the hydrogen comes from the _________ pole of the battery: ____

H. If the gas ratio produced by the reaction is not exactly 2:1 by volume, what explanation could account for this?

____

2. Take about 10 grams of sugar and place it in an old mason jar or other cheap glass vessel. (You can use a beaker, but it might ruin it.) Add about 40 ml of Conc. Sulfuric Acid, and watch what takes place. (The reaction is slow at first, so be prepared to watch it for about 15 minutes.) While waiting, you can proceed with #1 if possible.

A. When the reaction is proceeding, hold the bottom of a large beaker over the reaction vessel. What do you find?

____

B. When the reaction is essentially over, what reaction product is left behind? (CAUTION. IN VIEW OF THE SKIN BURNS FROM SULFURIC ACID, DO NOT TOUCH THE REACTION PRODUCTS)

____

C. In view of your knowledge of the dehydrating properties of sulfuric acid, and of your observations on the reaction, explain what seems to have taken place: ____________________

____

D. What kind of reaction did the sugar undergo? ______

E. What elements (if any) were formed during the reaction? ______________________________________

F. What compounds (if any) were formed during the reaction? ______________________________________

LAB UNIT #13: PERCENTAGE OF OXYGEN IN AIR

Since we all breathe oxygen to support life, you already must know that oxygen is one of the gases present in air; but how much is present? A simple experiment will show us the approximate percentage of oxygen in the air, as follows:

Take a small cork, and attach a small wood screw in the center of the smaller end. Make sure that it will still float. The metal should keep it in an upright position in the water.

Now take a small birthday candle (or a wooden matchstick will do) and place a small piece of it on the other end of the cork. Float the entire assembly in a large beaker or pan of water, large enough to measure at least five inches across.

The water should be close to room temperature.

Now take a 400 ml beaker, and quickly invert this over the burning candle floating on the water, making a water seal around the beaker so that the candle can only get air from inside the beaker. The water will slowly rise, and the candle flame will go out after a few seconds.

Lower or raise the beaker slightly in the water tank until the water levels inside and outside the beaker are the same.
WHY? ____
____

Now, carefully make a mark with a grease pencil, or attach a small label to show the water level inside the beaker. Then you can remove the beaker from the tank of water.

Measure:
1. The volume of the beaker up to your mark _____ ml
2. The volume of the beaker all the way to the top: __________ ml
3. The difference between (1) and (2) _____ ml

What does the difference (3) represent? _______________
____

By relating the difference (3) to the total volume (2), and multiplying by 100, we get a percentage figure for the amount of air used up by the candle flame:

$$\frac{\text{difference (3)}}{\text{total volume (2)}} \times 100 = \qquad \%$$

Since the burning of the candle is a process of combustion, what gas did it take out of the air? ____________________

Then what can you say about the percentage of oxygen in the air? About ____________% oxygen in air.

EXPERIMENTAL ERRORS: The actual average composition of oxygen in the air is about 21.0%. Of the remainder, 78% is nitrogen and 1% includes many other gases and water vapor.

DISCUSS the effect of the following various sources of error in your particular experimental value for the percentage of oxygen:

1. Did any air bubbles escape when you first lowered the beaker over the burning candle? If so, WHY? Also, what effect would this have on your final percentage of oxygen result?

2. If you started with water which was much higher in temperature, or much lower than the surrounding air, what effect would this have on your results?

3. If you marked your final water level without having the water levels inside and outside the beaker equal, what effect would this have on your results?

4. Depending upon just how you measured the volumes involved, work out some estimate of your actual error of measurement of volume, in terms of percentage.

Supposing you had put some moist iron filings on top of the cork in place of the candle, and set the experiment aside for a few days, what would you expect to find?

____

WHY? ____

LAB UNIT #14: SIZE OF AN OLEIC ACID MOLECULE

You might not think so, but it can be a rather simple matter to get an experimental value for the space occupied by one molecule. For this purpose, we will use a compound called OLEIC ACID because of its rather unusual property with respect to water. So in this experiment we will measure the area (cross section) of one molecule of oleic acid floating on the surface of water as a film. The unique property of oleic acid comes from its chemical make-up, as you will learn later this year; but the result is that small amounts of oleic acid placed on a water surface STAY ON THE SURFACE AND FORM A LAYER ONE MOLECULE THICK.

This is only true if you DON'T put on too much. If you put on too much oleic acid, the molecules have to go somewhere, and since the material is NOT soluble in the water, the molecules pile up on top of each other to form thick layers.

THIS IS GOING TO BE AN "EXPERIMENTAL TEAM" EFFCRT. Therefore, your instructor will divide your class up into small "teams", and each student will have certain specific things to do as part of his "team".

The experimental "team" approach is one of the newer techniques in scientific progress. The teams are composed of individuals whose strengths lie in different fields of thought and work, and who can thus contribute to each other in a cooperative effort. Like an athletic team, everybody on it must do his or her proper share of the working and thinking for the team as a whole to succeed. Also like an athletic team, even if you are not "carrying the ball" for a given moment, you must still pay attention to what goes on in case you are called upon to make an individual contribution in some way.

In order to function properly, each team member must be constantly alert to the whole "play", and keep the goal in front of him. He or she must be willing to contribute everything he can to the team effort, and to successfully meeting their goals.

TO THE TEACHER: A typical "team" can consist of four to six students, depending upon the size of your classes. The following team functions are listed, but (2) and (6) could be included under some other job if desired, and not be separate positions:

(1) Preparer of Oleic Acid Stock Solution
(2) Apparatus Assembler
(3) Experiment Performer
(4) Data Recorder
(5) Mathematician
(6) Cleanup Person

The roles of the above students will be obvious in the experiment, but the teacher will have to see that each job is done properly and at the right time.

OR, if you have a suitable student, you can put him/her IN CHARGE, and let that student "ramrod" the whole experiment. In this case, the teacher retires to the role of observer/ consultant.

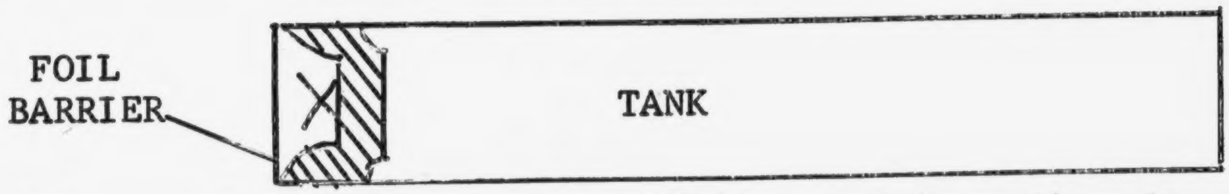
Your goal in this experiment, as mentioned, will be to get an experimental value for the area occupied by one molecule of oleic acid on a water surface. To do this, we will first need a very dilute "stock solution" of oleic acid in alcohol so that we can add very small amounts of oleic acid.

1. STOCK SOLUTION: Weigh out (or measure out) 0.10 grams of pure Oleic Acid into a clean, dry, glass stoppered bottle of 100 ml capacity, (NOTE: IF NO ANALYTICAL BALANCE IS AVAILABLE TO ACCURATELY WEIGH THIS QUANTITY, THEN USE AN "EYE DROPPER". ONE DROP EQUALS 0.05 grams of acid.) Add exactly 50.0 ml of alcohol to the bottle, stopper it, and shake.

This is your "stock solution", containing 0.1/50.0 x 100 = 0.2% of oleic acid.

2. APPARATUS: Obtain a glass, enamel, or plastic tank with rectangular dimensions, preferably a shape with the length considerably longer than the width, and the width not over 3" or 4". A glass bread baking dish would be suitable, for example.

Obtain some aluminum foil (used for wrapping food), and cut several pieces of foil in the shape shown here. There should be only a small clearance (a couple of mm or so) between the foil and the edge of the tank. A top view of the tank and piece of foil should look something like this:



SMOOTH your foil pieces out carefully, and keep them in a clean place until ready for use. CLEAN out the tank with detergent, and rinse with plenty of water. Set it aside upside down until ready for use. Get a millimeter rule, or a meter stick.

3. THE EXPERIMENT: Fill the tank with clean water, and with clean fingers take out one of your foil "barriers" and lay it on the surface of the water, close to one end as shown above.

A. Put one drop from an "eye dropper" of your Oleic Acid STOCK SOLUTION in the small space of water (X) BEHIND the barrier. Do this gently. Don't let it drop from a great height. The one drop can be assumed to have a volume of about 0.05 ml, and a weight (alcoholic solution) of about 0.04 grams (per drop).

The barrier should move a few inches down the walls of the tank.

B. When the barrier has stopped moving, CAREFULLY measure the length and width of tank BEHIND the barrier. Have the RECORDER write down these measurements.

C. IF THERE IS MORE ROOM FOR THE BARRIER TO MOVE, repeat steps A and B.

D. IF THERE IS MORE ROOM FOR THE BARRIER TO MOVE, repeat steps A and B AGAIN.

E. If there is no further room for the barrier to move, remove the foil, clean the tank again with detergent and LOTS of running water, and repeat A and B using a new foil barrier.

F. REPEAT THE EXPERIMENT so that you have THREE sets of data involving a weight of Oleic Acid, and an area occupied by that weight of Oleic Acid. For convenience, you can record the data here:

	No. of Drops	Weight of Oleic Acid	Area Measurement	Area cm^2
EXPT. 1				
EXPT. 2				
EXPT. 3				

G. MATHEMATICS: The gram molecular weight of Oleic Acid is 282.5 grams. According to a law called AVOGADRO'S LAW, one molecular weight of any material, IN GRAMS, contains 6.02×10^{23} molecules of that material.

From these two mathematical facts, calculate the weight of ONE molecule of Oleic Acid, in grams. __________ grams/one molecule

For EXPT #1 (above) calculate from the number of drops of 0.2% STOCK SOLUTION you used HOW MANY MOLECULES of Oleic Acid it contained:

____________________________ Molecules Oleic Acid/________ drops

For EXPT #1 (above) calculate the AREA occupied by that number of drops.

Area = ____________________ Squ. Cm.

Now, DIVIDE the AREA, by the NUMBER OF MOLECULES TAKEN in EXPT #1.

$$\frac{\text{AREA}}{\text{No. of Molecules}} = \qquad \text{SQU. CM/Molecule}$$

Repeat the calculations for each experiment and record the results:

EXPT #1 ____________________

EXPT #2 ____________________

EXPT #3 ____________________

AVERAGE OF ALL THREE RESULTS = ________________ SQU. CM/Molecule

LAB UNIT #15: BOYLE'S LAW

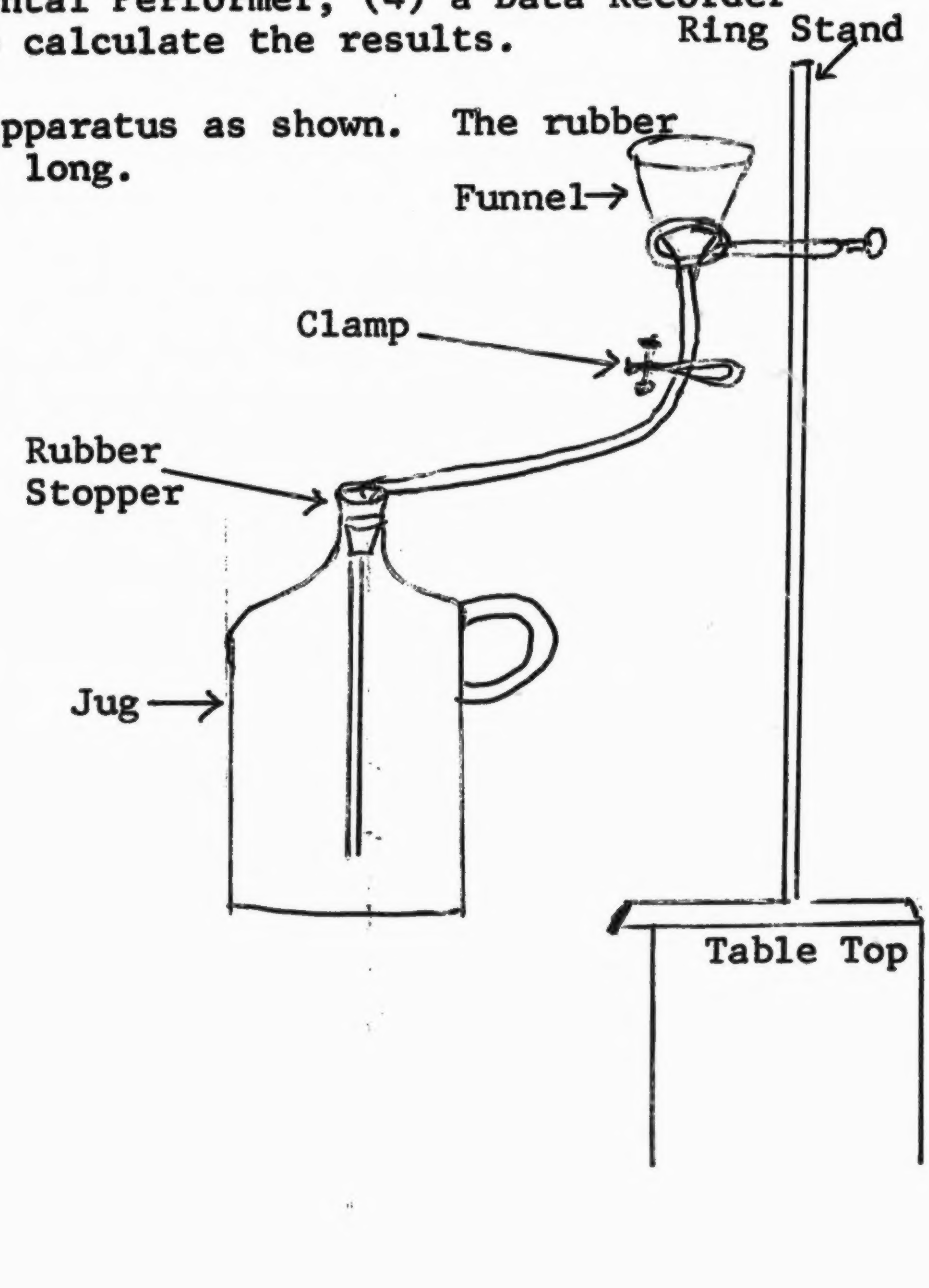
You have learned, or are about to learn, that the volume of a gas changes with the pressure upon it. The following experiment will show this, very much as described by Robert Boyle in 1661.

You will obtain numerical verification of Boyle's Law in this experiment, but the experiment has some critical points, and must be done properly to achieve good results. Since temperature can also affect the volume (or pressure) of a gas, we must assume that during this experiment the temperature does not change (it remains constant).

You will require a gallon jug, a meter stick, and other small items as shown.

Since the experiment is difficult to perform for one student, this is another place where we can use a "scientific team" effort. The instructor will appoint a (1) Experimental Director, responsible for the over-all effort, (2) an Apparatus Assembler, (3) an Experimental Performer, (4) a Data Recorder and (5) a Mathematician to calculate the results.

APPARATUS: Assemble the apparatus as shown. The rubber tubing should be about 18" long.



EXPERIMENT: 1. With the bottle on the floor, pour water into the funnel, and loosen the pinch or screw clamp until the entire tube is filled with water. Re-tighten the pinch clamp which should be tight enough to prevent water dripping from the end of the tube. At this point, the tube should be entirely full of water.

Remove any water that entered the jug during the above.

2. Insert the rubber stopper tightly into the jug.

3. Fill the funnel with water. Open the pinch clamp, and allow the water to enter the jug. Keep the funnel as full of water as possible while the water is flowing into the jug since you must not let any air get into the water column. Keep adding water and letting the water enter the jug until the back-pressure in the jug builds up to where it prevents the water from flowing any further, and the water level remains constant.

4. Close off the pinch clamp very tightly.

5. Measure the distance (in mm) from the floor to the top of the water column in the funnel. The Recorder should write down this value.

6. Measure the distance (in mm) from the floor to the top of the water level in the jug. Have the Recorder write down this value.

7. Now, carefully remove the entire water column assembly from the jug, taking care that you do not accidentally open the clamp or let any more water flow into the jug.

8. Measure (in ml, using a graduated cylinder) the volume of water in the jug. Record this value.

9. Measure and record (in ml, using a graduated cylinder) the volume of the jug to the bottom of the stopper position. Record this value.

DISCUSSION: Before water was allowed to flow into the jug, the air in the jug was subject only to the atmospheric pressure at the time you were performing the experiment. (Obtain this value, in mm of mercury, from reading a barometer or from a weather report.)

Allowing water to flow into the closed jug compressed the air in the jug, the amount of compression depending upon the height of the final water column. The height of the water column can be converted to pressure in terms of mm of mercury by dividing it by the density of mercury which is 13.5.

According to Boyle's Law, which you are trying to confirm experimentally, the volume of a gas will vary inversely as the pressure upon it. In this experiment, the original volume of the gas was that of the entire container (the jug), and it was under ordinary atmospheric pressure whose numerical value you can read (in mm of mercury) from a barometer. This volume and pressure is your first "set" of data for this gas.

With the funnel raised to a certain height, and water being allowed to flow into the bottle, the air in the jug will be compressed above atmospheric pressure. Its volume will therefore be reduced, in accordance (we hope, with Boyle's Law. When the water stops flowing, the height of the water column in the tube is a measure of the excess pressure being exerted on the air in the jug. By measuring this height, and converting it mathematically to an equivalent height of mercury (in mm), we can add this excess pressure to the barometric pressure, and get the total pressure exerted against the air in the jug.

Simultaneously, we can measure the reduced volume and compare it with the volume calculated by Boyle's Law from the higher pressure conditions. To simplify the concepts and arithmetic involved, the data can be recorded in the following table:

	EXPT. 1	EXPT. 2
1. Height of water from floor to top of water column in funnel (in mm):	______	______
2. Height of water in jug (in mm):	______	______
3. Total Volume of jug (in ml):	______	______
4. Volume of water in jug at end of experiment (in ml):	______	______
5. Volume of air in jug at end of experiment (under excess pressure) (in ml):	______	______
6. Barometric pressure (in mm mercury):	______	______
7. Height of water column causing excess pressure in jug (1-2 above (in mm):	______	______

INDEX TO LAB MANUAL--SEMESTER II

Special Chemistry Course Lab Manual

O.E. PROJECT 7G-045

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	EXPT. 1	EXPT. 2
8. Excess pressure converted to mm of mercury (value in Item 7 ÷ 13.5) (in mm):	______	______
*9. Calculated volume of air in jug under excess pressure (in ml):	______	______

To compare the actual measured volume of air under the excess pressure of the water column to the value calculated from Boyle's Law, compare (4) with (9) above.

Repeat the experiment using a slightly different height position for the funnel. Enter the readings in EXPT. 2 columns. Compute as before.

DISCUSSION: Your instructor will hold a group discussion to see how well your experiment was performed, and what errors entered into your measurements.

QUESTION: What other experimental factor is assumed to be constant during the performance of this experiment?

____

*For your calculations, use the following formula:

$P_1 \cdot V_1 = P_2 \cdot V_2$ Where: P_1 and V_1 represent your original pressure and volume conditions

Solve for V_2

P_2 represents your total pressure of atmosphere plus water column

V_2 will be your calculated volume of air in the jug under the new total pressure conditions

LAB UNIT #16: COMBUSTION--PYROTECHNICS

"Combustion" is a special case of oxidation reaction where the oxidation is rapid and accompanied by the giving off of heat and light energy. Pyrotechnics are combustion reactions of a special type, usually associated with fireworks.

Besides its general application on the fourth of July, pyrotechnics find applications in the military and other fields. For example, colored smokes play an important part in signaling, for both military and civilian applications.

In this unit we shall prepare and study some of the more enjoyable aspects of pyrotechnics.

1. FIRE INK: Weigh out about 5 grams of potassium nitrate, and place it in a test tube with about 2 ml of water. Warm gently to put the salt into solution.

With a small brush write on unglazed notebook paper using the above solution as an "ink". Make the lines of writing quite broad, say 1/8" to 1/4" wide. Set the paper aside to dry thoroughly.

After the paper is completely dry, touch a glowing splint or cigarette to the edge of the paper where the writing starts. If done properly, a glowing spark will travel along the path where you have written without burning the rest of the paper.

2. FUSE: Soak a piece of rough twine or heavy string in the rest of the solution of potassium nitrate above. Let it dry completely.

When dry, lay it on a metal surface and light the end with a match or glowing splint. The flame will travel slowly and at a fairly even speed. This is a "fuse".

For both (1) and (2) above observe closely as they burn. Do the paper and string both burn at the same speed? ________ Do both of them burn at an exactly even, predictable rate of burning? ____________

3. FIREPROOFING: Take a few wooden matches. Holding them by the head, dip them about half-way up their length into a solution of sodium silicate (water glass). Let them dry thoroughly.

When the matches are completely dry, light them. Observe what happens to the flame when it gets down to the coating of sodium silicate: ____

Could you see further applications of this in curtains for the home? ____

There are other chemicals which will retard or extinguish flame, and they are used extensively in homes, theaters, and business places to prevent fire loss and property damage.

4. MAKING SPARKLERS: The following formulas will make colored sparklers:

GREEN	RED
3 grams Potassium Nitrate	3 grams Potassium Nitrate
1 gram Barium Chloride	3 grams Strontium Nitrate
3 grams starch	3 grams starch
1 gram powdered Magnesium Metal	2 grams powdered Magnesium Metal
1 gram Charcoal	1 gram powdered Charcoal
10 grams water	10 grams water

Weigh out the required quantities above for each color, and mix the ingredients very completely until they form a smooth paste. Put a heavy coating of the paste on thin wooden splints, and allow several hours to dry. Also, pieces of string a foot or two in length can be mixed into the mixture and hung up to dry.

After drying completely, hold one end in a pair of pliers and light your sparkler. This is best seen at night or in a darkened room. These sparklers will burn your skin or clothing so take precautions against this.

What is the cause of the brilliant red or green colors in the above? ____

What would you put into one of the above formulas to make a yellow color? ____________________________________

In the above formulas, what is the function of the starch?

____

What is the function of the charcoal? ____________________

What is the function of the magnesium powder? ____________

The rusting of iron is also an oxidation reaction like the above. Why doesn't this reaction also give off heat and light? ____

LAB UNIT #17: HEAT

Heat is a form of energy. It can be transferred from one place to another by three methods: (1) radiation; (2) convection; and (3) conduction. Basically, heat energy is the result of random, unordered molecular motion, and all other forms of energy finally end up as heat energy. For example, a collision between two billiard balls will cause a small amount of energy being lost as kinetic energy (energy of motion), and this small amount of energy will appear as heat. All other energy processes do the same thing.

The basic unit of heat measurement is the calorie. This is the amount of heat energy needed to raise the temperature of one gram of water by one degree Centigrade.

(1) RADIATION: Light up your Bunsen burner. Hold your hand about six inches away from it, toward the SIDE of the flame. You can still feel some heat from the burner. This heat is being transferred to your hand by radiation.

(2) Take your largest beaker and fill it full of cold water. Set it on your tripod and put your Bunsen flame underneath the beaker, at one side. At the other side, away from the flame, drop in carefully a few large crystals of potassium permanganate.

As the water in the beaker is heated unevenly, "convection currents" are set up. The potassium permanganate will slowly dissolve, and help you trace the general path of these convection currents. Draw a small diagram below:

(3) CONDUCTION: Take a piece of glass rod or glass tubing at least eight inches long and hold one end in the flame till it gets red hot. Can you still hold the piece of tubing in your hands? ________________

Repeat this experiment with a piece of heavy copper or iron wire. Can you hold the piece of wire? ______________

The transfer of heat in this case was caused by: ___________

____

MEASUREMENT OF SPECIFIC HEAT OF IRON:

The same amount of heat energy will not give the same temperature increase with all materials. The number of calories needed to raise the temperature of a material by one degree Centigrade is known as its "specific heat".

The specific heat of water is about 1.00 calorie per gram.

We want you to design an experiment which will determine the specific heat of a piece of iron, and which you can perform using only the ordinary equipment which you have available in your laboratory.

What data will you need to get?

What equipment will you need?

What materials will you need?

When you have thought about this and had some time to design an experiment, see your instructor and check with him before going ahead.

_________________ INSTRUCTOR'S INITIALS

Next, go ahead and perform the experiment. This space can be used for your data and observations:

What EXPERIMENTAL VALUE did you obtain for the specific heat of iron: _________________

What UNITS go with this experimental value? _______________

The approved known value for the specific heat of iron at room temperature is about 0.11 calories per gram. Is your value higher or lower? _______________

What percent error did you get for your experimental value compared with the known value above? ______________________

LAB UNIT #18: ELEVATION OF BOILING POINT

In this Lab Unit we shall experimentally determine the change in boiling point caused by ionic and non-ionic solutes.

1. Since the boiling point even for pure water will vary with the barometric pressure (and altitude), put about 100 ml of distilled water in a beaker or flask, and heat it to boiling.

When the water has boiled for at least a few minutes, read the temperature as precisely as possible. (Better warm up the thermometer gradually so as not to break it by thermal shock.) Read the thermometer to the nearest 0.1° by careful estimation. Record the result:

BOILING POINT OF PURE WATER: ____________ (What units go with this?)

2. Figure out the molecular weight of METHYL ALCOHOL (CH_3OH). (CAUTION: POISON.) Weigh out this quantity of alcohol, and add it to 1000 grams of water. Mix to form a solution.

Take about 100 ml of this in a suitable beaker or flask, and determine its boiling point. Record the value:

BOILING POINT OF ONE MOLAL SOLUTION OF METHANOL: ________° C.

3. The molecular weight of glycerin is 92.1 grams. Weigh out this quantity of glycerin, and mix it into 100 grams of water to give a 10 MOLAL solution. Take and record the boiling point of this solution:

BOILING POINT OF TEN MOLAL GLYCERIN SOLUTION: _______° C.

4. Figure out the molecular weight of sulfuric acid, H_2SO_4. Weigh out this amount, in grams, and put it into 1000 grams of water. (CAUTION: ADD VERY SLOWLY AND STIR TO PREVENT ACID SPATTERING.) This will make a ONE MOLAL solution of sulfuric acid. Take any convenient quantity of this solution and determine its boiling point:

BOILING POINT OF ONE MOLAL SOLUTION OF SULFURIC ACID _____° C.

5. Figure out the molecular weight of sodium chloride (NaCl). Weigh out three times this quantity into 1000 grams of water. Determine and record the boiling point of this three molal solution:

BOILING POINT OF THREE MOLAL SOLUTION OF SODIUM CHLORIDE: ___________° C.

DATA SUMMARY:

Observed Boiling Point	Observed Elevation of Boiling Point	Observed Elevation per One Molal Solution	Theoretical Value for Elevation per One Molal Solution
1. Distilled water	none		
2. One Molal Methanol			
3. Ten Molal Glycerin			
4. One Molal Sulfuric Acid			
5. Three Molal Sodium Chloride			

QUESTIONS: 1. From the above, what essential difference do you find between methanol and glycerin, and sulfuric acid and sodium chloride?

____

2. Normally, pure water boils at 100.00° on the Centigrade Scale. Is this the value you found? __________
If not, WHY not? ______________________________

____

3. The standard value of the boiling point elevation for a one molal non-ionizing solute is + 0.512° C. What average value did YOU get for the two non-ionizing substances tested above? ____________________

What percentage difference is there between YOUR value and the accepted value? ____________________

4. If you wanted to cook food faster, does the above suggest a possible way of doing this?

____

5. What other way is frequently used to cook food faster? How does it work? ____________________

____

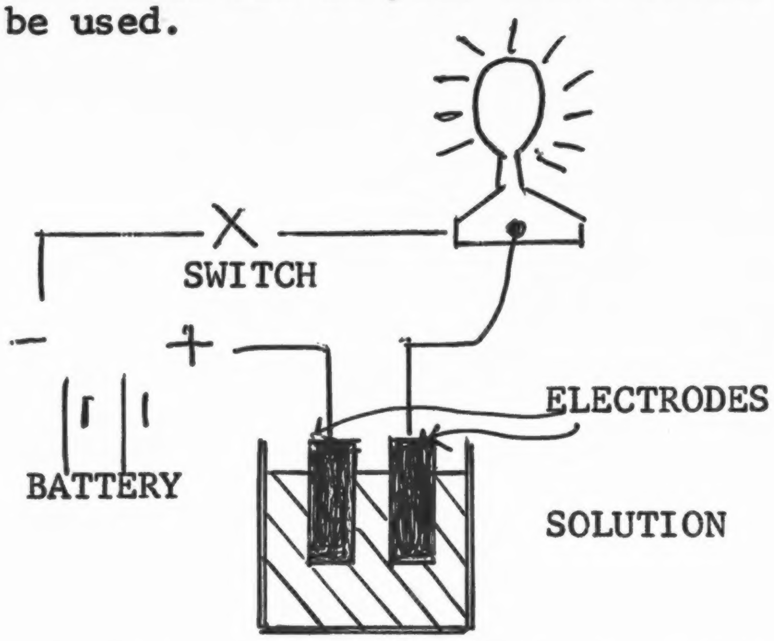
LAB UNIT #19: DEGREE OF IONIZATION

As we have learned in the previous Lab Unit, certain substances appear to "break down" in water solution to form additional particles. This unit will show you that these particles can carry an electrical current.

The amount of current which can be passed through a solution is logically related to the number of such charged particles, or "ions". Thus, the apparent "degree" of such ionization can be found by measuring the amount of current passed by a solution containing an electrolyte.

A rough indication of this effect can be obtained by putting a light bulb in series with a current source (such as a battery), and also in series with a beaker containing a solution. The current passing through the system will serve to light up the bulb, dimly or brightly, depending upon the number of ions available to carry the current.

Set up and wire together a simple set-up as per the diagram. A twelve volt battery can serve as a current source. Use a 12-volt bulb. The electrodes dipping into the solution in the beaker should be large metal plates at least 2" x 4". It is best to put a switch in series in the circuit so that you can turn the current on and off at your convenience. A 500 ml beaker should be used.



Prepare ONE MOLAR solutions of each of the following, using DISTILLED WATER: (Make 500 ml of each.)

	Molec. Wt.	Formula
Methyl (wood Alcohol (DANGER: POISON)	________	CH_3OH
Sugar	________	$C_{12}H_{22}O_{11}$
Acetic Acid	________	CH_3COOH
Phosphoric Acid	________	H_3PO_4

Calcium Hydroxide	____________	$Ca(OH)_2$
Sodium Hydroxide	____________	NaOH
Sodium Chloride	____________	NaCl

Make certain that the beaker you use is very CLEAN, and rinse it well between each usage.

When your apparatus is ready, fill the beaker up to a certain mark with pure distilled water, and close the switch. Does the bulb light up? (IF NECESSARY, DARKEN THE ROOM OR PUT A CARDBOARD CARTON AROUND THE LIGHT BULB so that you can observe it better.)

Open the switch and put TAP WATER in the beaker. Close the switch, and observe the bulb.

Repeat the above procedures with all of the light solutions.

Record your observations in the following table. A good way of making them "semi-quantitative" is to rank them from zero (for the least conductive) to 10 (for the most conductive), thus providing a ladder of values. This way your judgment can assign approximate numerical values for each observation.

Substance	Electrical Conductivity	Comments
1. Distilled Water		
2. Tap Water		
3. Methyl Alcohol Soln.		
4. Sugar Soln.		
5. Acetic Acid Soln.		
6. Phosphoric Acid Soln.		
7. Hydrochloric Acid Soln.		
8. Calcium Hydroxide Soln.		
9. Sodium Hydroxide Soln.		
10. Sodium Chloride Soln.		

QUESTIONS: 1. Can you think of any other possible reasonable explanation as to why some of the above substances, in water solution, should be able to carry electricity? (This would be a good topic for a class discussion.)

2. Taking the above data into account, along with the behavior of some of these solutes in elevating the freezing point, what do these two phenomena tell us regarding the behavior of certain solutes in water solution?

3. Discuss WHY a semi-quantitative "ranking" of observational values is better than just using words for describing experimental observations and results.

4. Explain your observations and results with respect to Calcium Hydroxide Solution as compared with Sodium Chloride Solution.

5. What is a "weak" acid?

6. What is a "strong" base?

LAB UNIT #20: ALLOYS

In your test you have learned already that one of the most interesting and useful properties of alloys is their unusual melting points. That, in fact, for any pair of metals taken together in the right proportion, there will exist a "Eutectic Point" which will be LOWER than the melting point of either metal alone.

Now, in general, in the solid state we have a situation very much like that in a liquid in that metals can:

1. be partly or fully "miscible" with each other to form what are called "solid solutions", or

2. be completely "immiscible" with each other to form on cooling a jumbled mixture in which both metals would still retain their own properties.

Mixtures of some metals also can form actual metallic compounds with a definite composition and a definite set of properties.

Situation (1) above can be likened to a solution of sugar in water. Copper and gold, for example, are completely miscible with each other, and can form a range of alloys over the whole composition range. Situation (2) can be likened to a mixture of sand in water. As an example, the metal pair iron and lead will not form useful alloys because they are not miscible.

In this experiment, we will make an alloy in the laboratory by melting together four metals according to the following ratio:

Bismuth,	50 parts	Tin,	12.5 parts
Lead,	25 parts	Cadmium,	12.5 parts

Pick a crucible large enough to hold about 50 grams of the metal. (You can figure this out since the alloy will have an approximate density of gms/ml.) Weigh out the proper amount of each metal according to the above formula.

Place the crucible on a clay triangle on a ring stand, and apply heat until the entire mass is melted. Mix it (CARE) with a piece of iron wire to make sure you get a uniform mixture.

After your alloy is completely mixed, start letting it cool down. But, as it cools, pre-heat a thermometer (HOW?) and insert it into the molten alloy to take its melting point.

Record the value here: Melting Point of Alloy: _______° C.

When the alloy is finally cold, take it out and handle it.

Color: ______________ Take its density: ___________ gms/ml

Let us make a comparison chart of some of the properties of the original metals, and that of the alloy:

Metal	Melting Point*	Color or Appearance
Bismuth		
Lead		
Tin		
Cadmium		
Your Alloy		

After you have done the above, heat a small beaker of water to the boiling point. Put your alloy into the boiling water. What happens? ____

QUESTIONS: 1. What can you say about the melting point of your alloy relative to that of each individual metal in it?

2. Why should you pre-heat the thermometer?

3. Can you think of any possible uses of the alloy that you made?

a)
b)
c)

4. Read a little, in other texts, about alloys, and try to find the name of the particular one which you made:

____

5. Does the alloy look the same as the individual metals which are in it?

6. How does the *density of the alloy compare with that of the individual metals which are in it? _______

____

7. Is there any metallic element which is a liquid at ordinary room temperature? ______________________

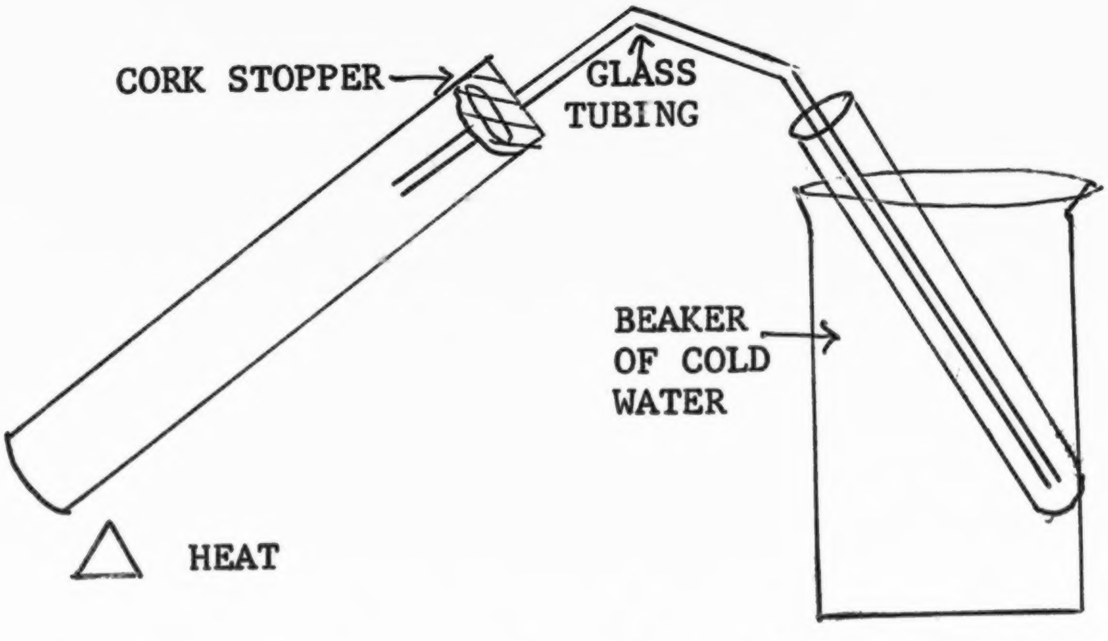
*You can look this up in another text or handbook.

LAB UNIT #21: WOOD DERIVATIVES

The purpose of this unit is to explore in the laboratory two of the ways in which wood can be broken down to give derived products. They involve two chemical processes: 1) distillation with which you are already familiar; and 2) digestion. The second process implies that one kind of material is being broken down by means of a "digesting fluid" into other simpler substances.

1. In this case, the process of distillation will be a "destructive" one. That is, we shall use heat to "crack" or "break down" complex molecules into simpler ones, and during the process the heat will also distill over whatever fractions are volatile. So the whole process is called "destructive distillation" because the original material we start with is destroyed as such.

We are going to make a small mess in this process so we do NOT want to use a regular condenser and distillation flask. Instead, take a HARD GLASS test tube (this is made from a glass that will stand more heat without breaking or deforming) about 6 or 8 inches long. Drill a cork to fit a piece of glass tubing (about 6 or 8 mm in outer diameter) and in turn to fit the mouth of the test tube. Bend a piece of the glass tubing, which should be about 8 inches long, as shown in the diagram below; and place the glass tubing in the cork.



In place of a receiver, use another test tube. Then in place of a condenser, since we will not get a large quality of material distilled over, place the test tube in a beaker of cold water. Assemble the entire apparatus in such a way that you can heat the hard glass (or Pyrex) test tube with your burner.

In the hard glass test tube place a few grams of wooden splints or some other kind of wood chips. For example, shavings will do.

Stopper the test tube tightly with the cork, and heat the tube gradually at first, and then more strongly. Try to keep your flame away from the cork, or it will burn also.

The vapors coming from the destructive distillation of the wood will pass through the tube into your receiving test tube, and the cold water outside of this test tube will make them condense inside your test tube receiver.

When you no longer can get any further product distilled from the wood, stop the heating, and withdraw the end of the delivery tube from the receiver. Let everything cool down.

While the heated test tube is cooling, examine the liquid contents of the other tube for color, odor, etc. Spill some on your fingers and taste a little of it. Can you identify any of the distillation product? Put a drop or two on a piece of filter paper and examine it again. Products? ________________________
Litmus color? ______________ Touch a piece of red and a piece of blue litmus paper to the distillation product. What happens?
____

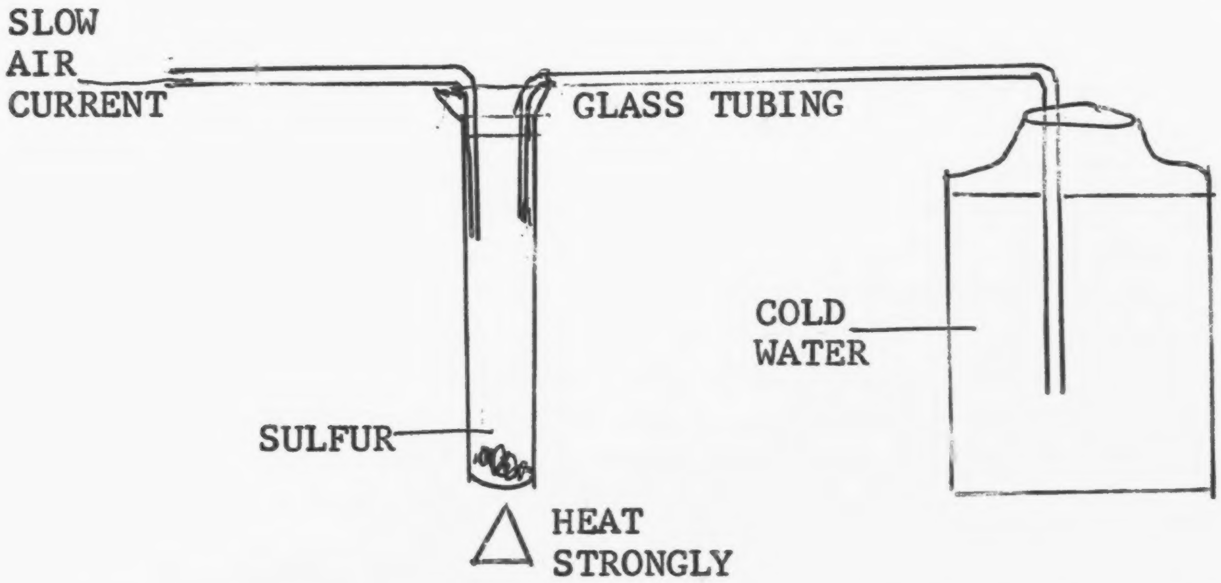
By this time the heated tube will be cool enough to touch. Invert it over a piece of clean paper, and tap it to help remove the contents. Examine the charred product. Smell it. Taste it. Feel it. What do you think it is? _____________

2. In this part of the experiment we shall make a little "wood pulp" and play with it. Since the digestion process which separates the wood fibers is rather slow, you will not be able to do this all in one day so you should get this experiment started today, and finish it the next lab period.

Also, next lab period one of the girls in the class should bring an electric iron to the lab. We will need this.

Obtain several ounces of wood shavings or sawdust. With a knife cut the pieces until they are quite small. (This will speed up the digestion process.)

Make some sulfurous acid by burning a few grams of sulfur in a test tube in the presence of air, and catch the resulting gas (sulfur dioxide) in a bottle of cold water. A possible setup to do this would be as follows:



To make the acid as concentrated as possible, keep adding sulfur dioxide gas until no further solution seems to be taking place. USE THE HOOD. Otherwise you will be very unhappy breathing this gas. If a hood is not available, set the apparatus by an open window, and blow the fumes outside with an ordinary electric fan.

When you have gotten the small wood chips, put about 50 grams of them in a beaker, and add plenty of your sulfurous acid. Also, add some Sodium Sulfite or (if not available) some Sodium Hydroxide. Heat the beaker over a LOW flame, or with a small electric hot plate. You want to keep it warm for a day or two, but not so hot you boil off all the liquid.

NEXT LAB PERIOD:

If you had enough sulfurous acid (or Sodium Sulfite) present, and kept the digestion mixture at an elevated temperature for a long enough time, you will have dissolved out the lignin which holds the cellulose fibers together.

Testing with litmus paper, add enough Ammonium Hydroxide to neutralize the sulfurous acid in your beaker, and then wash the "wood pulp" which you have made, using the process of "decantation". Decantation means that you add a liquid, mix it with the solids to be washed, let the mixture settle as much as possible, and pour off the clear liquid on top.

So try to wash your wood pulp by decantation. If it takes too long, you may have to filter it, or possibly pour it through a wire screen.

Next, obtain a fairly clean piece of wire screen (such as used for window screens). A clean laboratory wire gauze would be suitable also. Pour your wood pulp onto the piece of screening, trying to get an even layer. With a test tube, or the bottom of a beaker, squeeze or roll the pulp to get as even a coating as possible.

Finally, suspend the piece of screening (with the wood pulp on it) over a heater to help get it dry. If you use a burner, DON'T let the pulp burn.

When it is ALMOST dry, carefully loosen the flat pulpy mass, lay it down on a flat surface, and iron over it with an electric iron.

The result of the above is that you have produced a sheet of PAPER. It may not look very good, and it may not be very flat or very white, but it is still PAPER; and the process you just went through in a brief period of time took the world untold centuries to learn and brought on our modern industrial and technological revolution.

Handle your piece of paper. Bend it. Write on it. Smell it. Industrial paper making machines which do the same thing, but on a larger scale, cost hundreds of thousands of dollars. However, in a few small countries (England, France) a few people still make paper BY HAND just like you did. Their product sells to artists, for the painting of water color pictures, and a sheet sells for about $2 even today.

Let's ask ourselves a few questions on the above:

1. Since we have learned a process of destructive distillation, is there a process called "constructive" distillation?

2. WHY should you withdraw the end of your delivery tube from the receiving vessel as soon as you stop heating?

3. WHY did your litmus paper turn color in the distillate? What kind of chemical substance must have been present to do this?

4. WHY do we have to add some Sodium Sulfite, or some Sodium Hydroxide to our digestion solution?

5. When your solution of sulfurous acid was boiling, or close to boiling temperature, did you notice whether any gas was escaping from it? If so, what gas? In general, do gases seem to be more or less soluble in water at higher temperatures?

____

6. According to the questions in (5) above, the solution loses gas on boiling. Would this be one possible way to purify a solution containing a dissolved gas?

7. How could you have converted your paper making operation to a continuous operation, instead of the "batch" process you used? Discuss the requirements and equipment both for the

digestion process and for the paper making process, just as if you were an engineer faced with this problem.

8. Why isn't it too good for you to breathe in sulfur dioxide gas? What compound does it form in your lungs?

9. What other things could you have done to the pulp to make an improved paper sheet?

10. Discuss the advantages and disadvantages of washing suspended solids by "decantation" as compared with "filtration".

LAB UNIT #22: THE HALOGENS

Early in this course, you made some elementary Chlorine and studied its properties (Lab Unit #9). This element is an important member of the Halogen Family, and in this Lab Unit we want to take a closer look at some other members of this family. As you are learning in your text material, the element Fluorine is one of the "guys with the black hats"--under certain circumstances he can get pretty rough. Therefore, we will omit a closer acquaintance with Fluorine. Bromine and Iodine can be bad enough. Based on the fact that Chlorine is not very good to breathe, TAKE SUITABLE PRECAUTIONS in this experiment also so that you do not burn your skin or breathe in too much of their vapors.

If desirable to refresh your memory, refer back to your notes on Lab Unit #9.

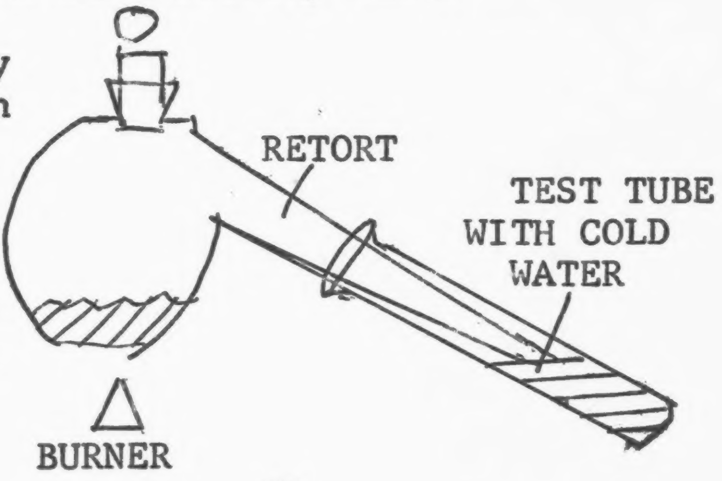
1. A. BROMINE: This will be made by a process similar to that by which we produced Chlorine.

Obtain a glass "retort" (if one is available) and arrange to clamp it in a ring stand so that it can be heated with a burner. (See Diagram.) If a retort is [illegible] available, use a small flask fitted with a cork and delivery tube.

Since Bromine vapors are easy to condense, arrange to catch them in a test tube partly filled with cold water. The Bromine, which is a heavy liquid, is NOT very soluble in water, and therefore will form a separate layer in the bottom of the test tube.

In your retort (or flask) place about 2 grams of KBr and 1 gram of Manganese Dioxide. Add about 10 ml of DILUTE H_2SO_4 (1 acid to 4 water).

Fit the delivery tube (or the end of the retort) so that it dips into the cold water in the test tube, and WARM THE RETORT GENTLY. Collect the Bromine vapors until the reaction is finished. When finished, immediately disconnect the apparatus, and wash it.



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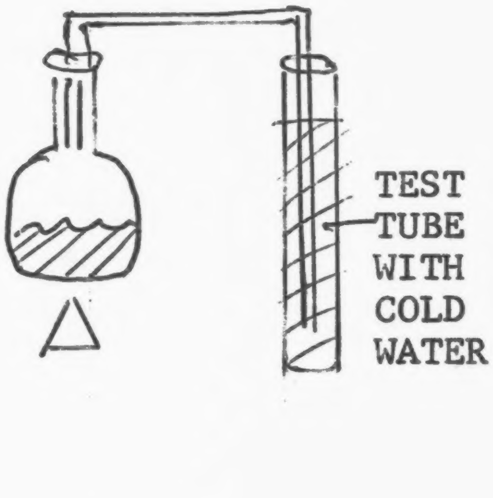


B. PROPERTIES OF BROMINE:

(1) Put a few ml of Alcohol, Chloroform, and Carbon Tetrachloride in each of three test tubes. To each one add a little of your "Bromine Water". Note the colors formed:

Alcohol: ______________ Chloroform: ______________ Carbon Tetrachloride: ______________

(2) Now in another test tube dissolve a little potassium iodide (KI) in a few ml of water, and add a little of this potassium iodide solution to each of the above test tubes. Shake each one. What happens? ____________________

Alcohol: ________________ Chloroform: ______________ Carbon Tetrachloride: ________________-

(3) CAUTIOUSLY SMELL your Bromine Water. Describe the odor: ____

(4) Is Bromine more soluble in water, or in the other three solvents you tried? __________________________

(5) Can you explain the color changes in (1) and (2) above? ____

QUESTIONS: 1. The above instructions told you to continue the experiment until no more Bromine was formed. Apparently, this experiment "went to completion". WHY?

2. The above instructions told you to "disconnect your apparatus" as soon as the reaction appears to be finished. WHY is this instruction important? What can happen if you don't follow it? ______________________

2. A. PREPARATION OF IODINE:

In a 250 ml beaker placed on a gauze and ring stand or tripod place about 2 grams of potassium iodide and 2 grams of manganese dioxide. Add about 10 ml of DILUTE sulfuric acid (1 acid to 4 water).

Cover the beaker with an evaporating dish filled with COLD water to act as a condenser. Gently heat the reactants in the beaker. What is the purple vapor? __________________
What is the process called by which iodine passes directly from the solid state to the vapor state? __________________

B. PROPERTIES OF IODINE:

(1) Scrape off a little of the solid iodine. What

(2) Dissolve a little of the Iodine in a few ml of the 3 solvents. Colors? Alcohol: ____________ Chloroform: ___________ Carbon Tetrachloride: _______________

(3) If you happen to have an open cut, you can put a little of your Iodine/alcohol solution on it as a disinfectant. However, you will feel it.....!

(4) Put a few crystals of Iodine in a test tube containing water and shake. Is Iodine very soluble in water?

____

QUESTIONS: 1. In the light of the colors formed when Bromine dissolves in the three solvents mentioned, and the colors formed when the elementary Iodine dissolves in the same three solvents, NOW can you explain the color changes you found in 1 B. above? ____

2. Of the two elements Bromine and Iodine, which appears to be MOST REACTIVE (that is, which one prefers to be in the combined state rather than as the element)? _______

3. Can water go directly from the solid to the vapor state? Before you answer this one, what happens to wet clothes hung outside to dry in the winter time? Do they ever get dry?

4. Remembering your work with Chlorine in Lab Unit #9, what common items also apply to Bromine and Iodine?

a. Do they seem to be metals or non-metals?

____

b. Are they all colored? _______________

c. Are they all apparently poisonous or injurious to human life? _______________________________

d. Are they all gases? _________________

e. List Chlorine, Bromine, and Iodine in their approximate order of solubility in water according to your rough observations:

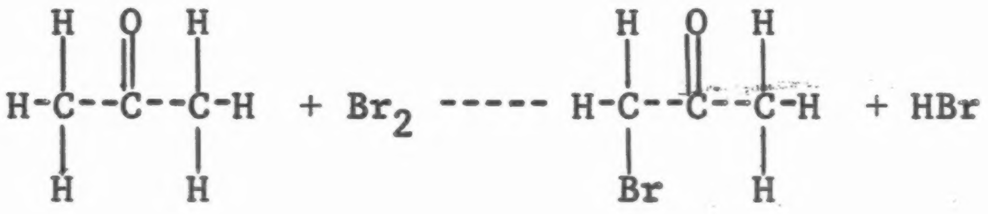
___________	_____________	____________
most soluble	medium soluble	least soluble

3. A. PREPARATION OF A BROMINE COMPOUND: BROMOACETONE

Acetone is a common "organic" solvent obtained, among other things, from the destructive distillation of wood. Also it can be made "synthetically" in the laboratory. You have just used some of it in the early part of this experiment.

Under prolonged contact with the element Bromine, Acetone can react with it to form the compound called "Bromoacetone". This compound is used as a "tear gas". We shall make some of this.

The formula of Acetone is $(CH_3)_2CO$, but its structure can be shown better by using the so-called "structural formula" which shows the arrangement of the various atoms with respect to each other:



$$H{-}C{-}{-}C{-}{-}C{-}H + Br_2 \text{ ----- } H{-}C{-}{-}C{-}{-}C{-}H + HBr$$

Notice that a bromine atom has replaced a hydrogen atom. The second bromine atom combines with the hydrogen atom which was replaced to form Hydrogen Bromide.

The above reaction is somewhat typical in that the halogens frequently can and do react with "organic" compounds to form a large variety of interesting and useful materials.

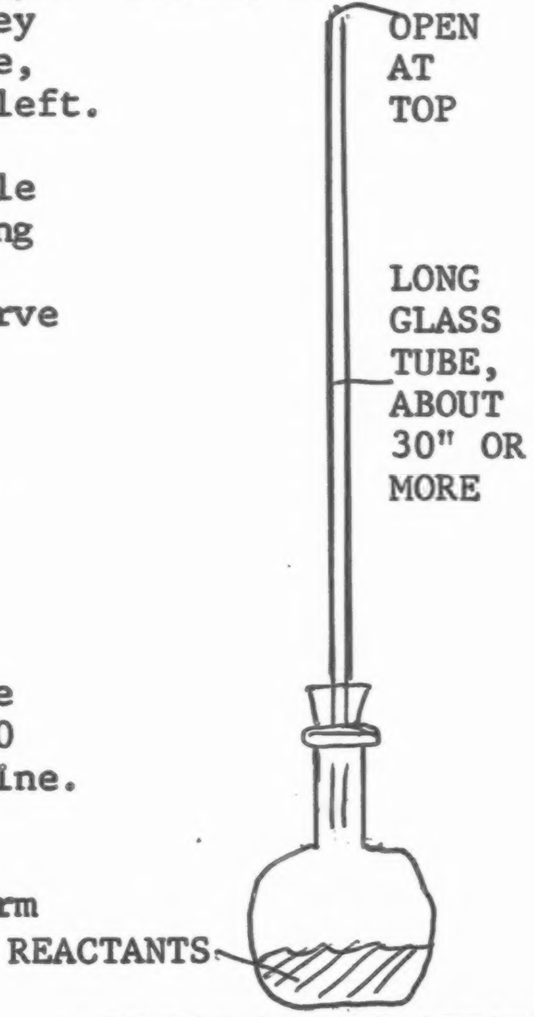
The formation of Bromoacetone is very simple in that Bromine and Acetone should be weighed out and kept in prolonged contact in a warm place for several days. Since, however, both materials are quite volatile, they would evaporate in this period of time, and you would have little or nothing left.

Therefore the chemist attaches a simple type of condenser in the form of a long piece of glass tubing. No water is needed as the surrounding air will serve to cool the vapors enough to prevent their escape.

The experimental setup is as shown in the diagram. This process, where we perpetually distill and redistill something, is called "refluxing".

In your small flask put any reasonable amount of both reactants, say about 50 grams of Acetone and 25 grams of Bromine. Set aside for several days.

NOTE: Just set the apparatus in a warm place, in the sun, or near a steam radiator. DO NOT USE DIRECT FLAME BECAUSE acetone is very flammable.



A SIMPLE REFLUX APPARATUS

After several days, take the apparatus apart and examine the contents. Be careful NOT to get any of the product or reactants into your eyes. Does its appearance and odor differ from that of the original reactants? ________________

As mentioned, Bromoacetone is used as a tear gas. Is it effective for this purpose? ________________

QUESTIONS: 1. From a practical viewpoint, WHY did we use a large excess of Acetone to start the experiment? (According to the equation above, only about 10 grams of Acetone are needed to react with 25 grams of Bromine.) ________________

____

2. Do you think that using an excess of one of the reactants would make a reaction go further towards completion? ________________

3. Is the shape of the flask important?

LAB UNIT #23: ANALYSIS OF MINERALS

In our Southwest the mining industry plays a large part in our economy. The entire industry starts with the lonely prospector wending his weary way among the desert sands and brush, looking for something that can be of value to himself and the world.

Usually, these people work by experience. Over the years they have learned what the different minerals look like. However, since a mineral is defined as any pure inorganic substance, there are literally thousands of minerals, and most prospectors can recognize only a few dozen at best. A more scientific approach is to be able to chemically "analyze" a mineral to tell what elements are present.

Ordinarily we don't run a "complete" analysis. This would take an absurd amount of time, effort, and skill, so we usually look only for a relatively few metals (or non-metals) of special value. Identifying "what" elements are present is called qualitative analysis. There are quite a few methods by which we can approach this problem, and in this Lab Unit we shall study briefly several of those methods.

1. THE FLAME TEST: All metals when heated to a high temperature give off a characteristic "spectrum" of electromagnetic radiation. In a few cases, this spectrum is quite distinctive, even in the visible light range, and results in a distinctive "color" being emitted.

To obtain this distinctive color, a small amount of the metal (usually dissolved as the chloride because the chlorides are fairly volatile at high temperatures) is heated in a flame. The metal salt is held usually on a piece of platinum wire since pure platinum itself will not emit a visible color, and the wire in turn is held in a piece of glass tubing so that we can hold it without getting burned.

Make up a few ml of 1% solutions of each of the following:

a. lithium salt
b. sodium salt
c. potassium salt
d. calcium salt
e. strontium salt
f. barium salt

(If the chlorides are not available, any other salt of the above metals will serve.)

Take a clean platinum wire, and dip it in a little Conc. HCl, and then hold it in a flame. Repeat this until the wire gives a fairly "uncolored" flame. If necessary, use a piece of fine sandpaper to help clean it off.

Now dip the wire into the lithium solution, and hold it in the hottest part of the flame. Observe the color.

After each metal solution, repeat the cleaning process with Conc. HCl so that you do not contaminate the next solution by using a "dirty" wire. Observe and record the colors.

IF NECESSARY FOR PROPER OBSERVATION, DARKEN THE ROOM OR ERECT A TEMPORARY LIGHT SCREEN WHERE YOU ARE WORKING.

In the following table, record your results from the flame test:

a. lithium color ________
b. sodium color ________
c. potassium color ________
d. calcium color ________
e. strontium color __________
f. barium color _________

Now, have your teacher give you an "unknown" compound containing one of the above metals, and try the flame test on it.

Results on unknown ______________ Metal Identified: ___________

Were you right or wrong in your identification ______________?
(If you were wrong, it probably would be due to using a "dirty" wire which could give you an incorrect test result.)

2. SODIUM CARBONATE BEAD TEST: A few of the useful metals give a particular color when present in a "bead" of sodium carbonate.

To perform this experiment, take your clean platinum wire and form a tiny "loop" at the end of the wire. With this loop, scoop up a small amount of sodium carbonate and heat it in the flame until it melts. Repeat until you have a small "bead" up to about 1/8" diameter.

NOW take up (one at a time) a small amount of each of the following solutions on your "bead" and remelt the bead in the flame. Let the bead cool, and observe its color.

a. Manganese chloride (or any other manganese salt).
Bead color: ____________________

b. Chromium chloride. Bead color: ________________

Other materials also give colored beads with different metal salts. Borax is sometimes used for this purpose.

3. CHEMICAL TEST:

Copper: Put a small amount of any soluble copper compound in a few ml of water and shake to dissolve it. Now add a few ml of a 2% solution of POTASSIUM FERROCYANIDE. Color: ________________

Iron: Put a small amount of any soluble iron compound in a few ml of water (or dissolve part of a nail in a little HCl). Now add a few ml of 2% solution of POTASSIUM FERROCYANIDE. Color: _____________

Nickel: Dissolve a small amount of any soluble nickel salt in a few ml of water. Add Ammonium Hydroxide until slightly alkaline. (Can tell this by faint smell of ammonia.) Now add a small amount of 1% solution (in alcohol) of DIMETHYL GLYOXIME. Color: ________________

4. BLOWPIPE TEST: In this test a small amount of the metallic mineral is placed in a shallow depression in a block of charcoal, and then heated strongly in the flame of a "blowpipe".

CAUTION: DO NOT BREATHE IN when holding the blowpipe in the flame.

The blowpipe flame volatilizes certain minerals, and they may form characteristic colors on the charcoal block. Since the flame of the "inner" cone of the blowpipe will give a chemical reducing action, and the flame of the outer cone a chemical oxidizing action, two separate effects may be obtained.

Lead: Take a tiny amount of some lead compound, and place it in a small depression on your charcoal block. Heat it strongly with the blowpipe flame for at least one minute. Let it cool, and examine the colors on the block carefully. Colors: ___________________

Zinc: Put a small amount of a zinc compound on the charcoal block, and heat it strongly with the blowpipe. Colors: ___________________

Copper: Put a small amount of copper compound on the charcoal block, and heat it strongly with the blowpipe. Colors: ___________________

UNKNOWN MINERAL: Your instructor will give you a small piece of an unknown mineral. Try, one after another, the following tests:

1. Flame Test
2. Carbonate Bead Test

3. Chemical Tests (dissolve ore in Conc. Nitric Acid)
4. Blowpipe Test

Can you identify one or more metals in your unknown piece of ore?

__________________ _____________________ _____________

There is a great variety of useful tests, of which the above selections are merely a brief assortment; but they will serve to introduce you to the different methods of mineral analysis.

Sometimes the above methods are combined with physical tests such as Density, Hardness, Refractive Index, etc.

Density: Take a small piece of ore and determine its density as accurately as possible. All you need is a balance (to weigh out a small portion), and a Graduated Cylinder (to get the volume of your weighed portion).
Results: ____________________

6

LAB UNIT #24: REACTION RATE AND EQUILIBRIUM

In this Lab Unit we shall take a look at some of the factors which can change the speed of a reaction and at some of the factors which can shift the equilibrium of a chemical reaction.

REACTION RATE: 1. TEMPERATURE. Place a gram or two of sodium chloride in a small beaker and pour over it about 5 ml of Conc. H_2SO_4.

Observe any results for a minute or two. Then place the beaker on a wire gauze and ring stand, and gently heat the bottom. Observe and smell (CAUTIOUSLY) any reaction product.

What can you say about the influence of temperature on the speed of the above chemical reaction? ______________________

____

2. STATE OF SUBDIVISION. Take two small beakers of equal size. In one place one gram of POWDERED Zinc metal. In the other place one gram of MOSSY Zinc.

Now, pour 10 ml of Dilute H_2SO_4 (1 Acid/4 Water) into each beaker. Observe the results over a minute or two.

What can you conclude about the influence of the state of subdivision of a reactant upon the speed of a reaction?

____

____

Why are we supposed to chew our food when we eat?

____

3. CONCENTRATION. A. Weigh out one gram of Barium Chloride and put it in solution in a beaker, using 10 ml of water.

In another beaker weigh out one gram of Conc. H_2SO_4 and put this in solution in 10 ml of water.

Now quickly pour one solution into the other, and observe the results. The white material formed is Barium Sulfate. (SAVE IT FOR LATER USE.)

B. Now in a gallon jar weigh one gram of Barium Chloride and dissolve it in about one-half GALLON of water.

In another gallon jar weigh out one gram of Conc. H_2SO_4 and add about one-half gallon of water.

Then quickly add the contents of one jar to the other. Observe the results.

What can you say about the effect of concentration on the speed of a reaction? ______

4. What other factor which we have not considered yet in the laboratory can influence the speed of a chemical reaction? ______

Is this factor able to influence ANY chemical reaction, or only certain ones? If so, which ones? ______

SHIFT OF CHEMICAL EQUILIBRIUM: REACTIONS THAT GO TO COMPLETION:

1. Take the suspension of precipitated Barium Sulfate that you made under part 3.A. (above) and filter off the precipitate.

To the clear liquid that went through the filter (this is called the FILTRATE) add a few drops more of dilute sulfuric acid. Do you get any further precipitate formed? ______

If you did NOT get any further precipitate of Barium Sulfate, then obviously that particular chemical reaction "went to completion". WHY DID IT? ______

2. Take a gram or two of Calcium Carbonate in a small beaker and add 10 ml of Dilute H_2SO_4 (1 Acid/5 Water).

Does a reaction take place? ______ How do you know?

______

Stir the mixture a little while, and when you think that the reaction is all over, add another 10 ml of dilute acid. Does anything further happen? ______

If, on the second addition of acid, no further reaction occurred, then obviously this reaction "went to completion". WHY did it? ______

Can you name the gas given off during the above reaction? ______

3. Name a third method by which reactions can be made to go to completion. ______

4. In a neutralization reaction, usually an acid will continue to react with a base until the acid is used up. Which of the above devices is used in making neutralization reactions go to completion? ______

______

LAB UNIT #25: QUALITATIVE ANALYSIS: PAPER CHROMATOGRAPHY

In the Lab Unit on Mineral Identification, you have been introduced already to some methods of Qualitative Analysis which tells us WHAT KIND of elements may be present in a mixture or compound.

In this Lab Unit you will learn about another such method based on a physical method of separation called Paper Chromatography. In this method a small quantity of sample is placed on a piece of filter paper, and a solvent mixture is allowed to flow over the sample by wicking action. The sample will be a solution containing different metals. As the solvent flows past the sample and over the paper, it redissolves the metal ions which then migrate over the paper. Since the paper has a different affinity for each kind of metal, some of the metal ions will be carried only a short distance from their origin, and some will be carried further.

At the end of the solvent action the paper is dried, and the presence of the metals in different absorption bands or "zones" can be shown by the use of reagents which will make them become colored.

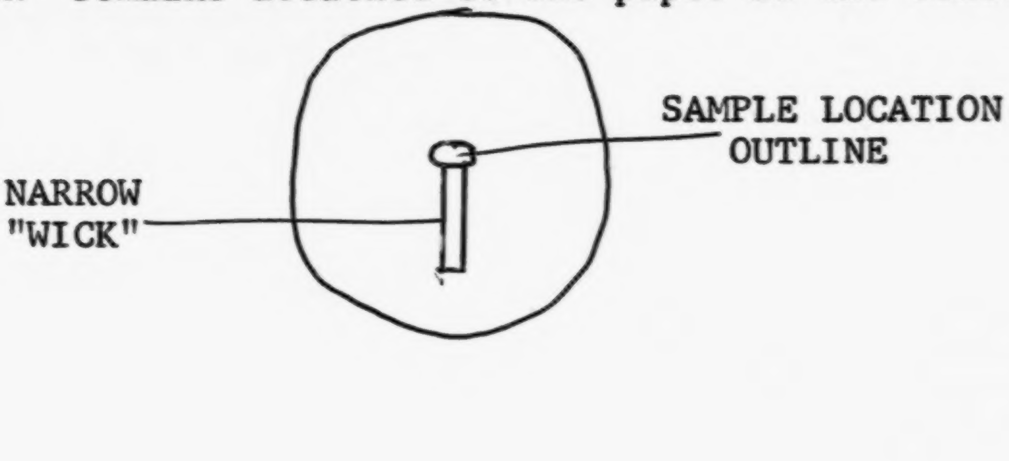
For this experiment we shall use a reaction chamber composed of a Petri Dish, and a metal mixture containing 1% each of IRON, NICKEL, and COPPER in nitric acid solution.

PART I:

Prepare (or the teacher may furnish to you) a solution of the nitrates of iron, nickel, and copper in which each metal is present to the extent of 1% by weight.

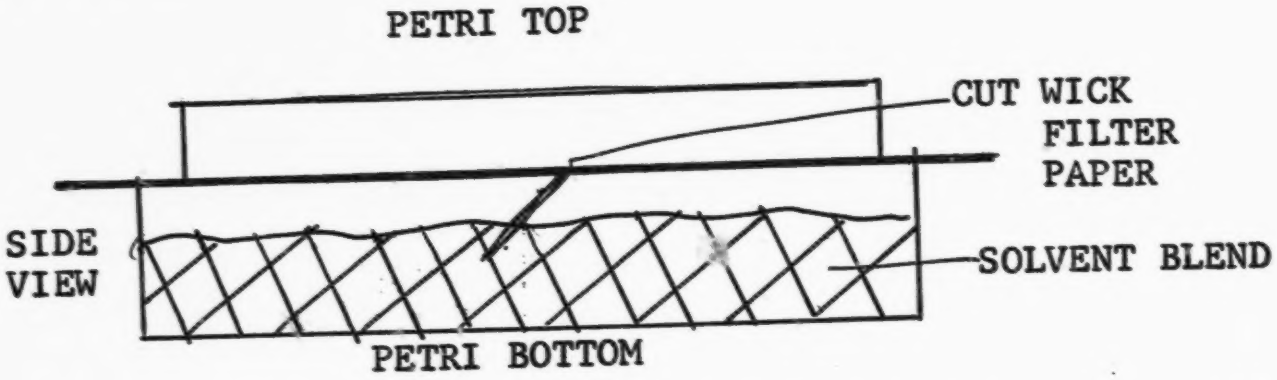
In the middle of a piece of 12.5 cm diameter filter paper draw a small pencil circle about 1/4 inch diameter. In this circle put a PARTIAL DROP of your metal mixture solution (above). Let this DRY.

When the sample spot is completely DRY, take a razor blade and cut a small WICK, as shown in the diagram: (NOTE that the "wick" remains attached to the paper at the center.)



While the sample is drying, mix together your SOLVENT BLEND which is composed of: 10 ml ACETONE, 10 ml CHLOROFORM, 10 ml ISO AMYL ALCOHOL, and 5 ml CONC. HYDROCHLORIC ACID. Put 30 ml of this Solvent Blend into the BOTTOM part of a Petri Dish.

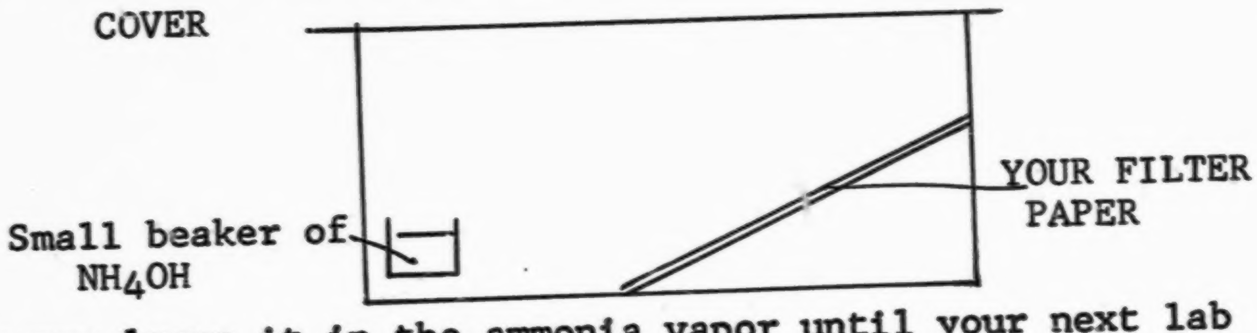
Push the paper "wick" towards one side of your filter paper and lay the paper on the Petri Dish containing solvent so that the wick dips into the solvent layer. Then put the other half of the Petri Dish on top as a COVER. The whole assembly will look like this:



Allow the solvent action to proceed for about 2 hours until the solvent band gets near the outer rim.

YOU MUST STOP THE PROCESS when the solvent gets near the outer edge of the Petri Dish. This takes about two hours. Therefore, your teacher or one of the students will have to keep an eye on this experiment until each one gets to the proper point.

When the solvent gets near the edge of the paper, REMOVE THE PAPER FROM THE SOLVENT, and immediately PUT IT IN A COVERED DISH WITH AMMONIA VAPOR PRESENT.



You may leave it in the ammonia vapor until your next lab period if you like.

COLOR DEVELOPMENT: In order to identify each metal present, which now has been separated on the paper into a separate "band" location, we will use a solution of 1% RUBEANIC ACID in alcohol. With this reagent two of the metals will give colors as follows: (For the third metal, iron, we will use a 3% solution of Potassium Ferrocyanide in water.)

NICKEL METAL - dark BLUE

COPPER METAL - dark GREY

IRON METAL - dark BLUE-GREEN

Cut your filter paper in half, and with an eye dropper flow some of the Rubeanic Acid solution over one-half of the paper. Then again expose the paper to AMMONIA VAPOR.

There should be two clearly defined and separate bands on the paper, each one has a different color. Record the colors of the bands. Now do the same thing for the other half of your filter paper, using Potassium Ferrocyanide solution:

1.____________________ 2. ___________________ 3.__________

What metals have you identified? 1. _____2. _______ 3._____

We can go one step further by computing what is called the "R_f" Value for each metal. To do this, take a Millimeter Ruler and measure the distance from the CENTER of the paper (where you put the sample spot) to the OUTER EDGE of each colored band. Also measure the distance from the CENTER to the SOLVENT FRONT. (Actually the iron band goes right with the solvent front so you can measure the distance from the center to the edge of the iron band.)

To locate accurately the iron band on your half filter paper containing the nickel and copper test, you can match the two halves so that the test for iron will serve to locate the solvent front on the other half.

Now to compute the R_f value, this is simply the RATIO of the distance from the CENTER to each METAL BAND as compared with the distance from the CENTER to the SOLVENT FRONT. As mentioned, for IRON this ratio will be 1.00 since iron travels with the solvent front itself.

Compute the R_f ratio for COPPER and for NICKEL. Record your values here:

		KNOWN VALUES	PERCENTAGE DIFFERENCE
COPPER R_f =	____________	0.68	
NICKEL R_f =	____________	0.18	
IRON R_f =	1.00	1.00	0.0%

In the system you used, NICKEL usually shows an R_f ratio of about 0.18 and COPPER usually an R_f ratio of about 0.68. Assuming the KNOWN VALUES to be correct, what percentage difference are your values? Compute this, and enter the percentage difference in the spaces above.

Do you think you could separate and identify these three elements in a mixture? ________________

There are other "media" besides filter paper that can be used for chromatography, and other solvent blends, depending upon the materials you are trying to separate. Also, in recent years medicine has begun to make tremendous usage of paper chromatography as a "diagnostic tool". For such clinical work, they use the various body fluids such as mucous, blood, spinal fluid, etc.

In the case of medical/clinical usage, they do not look for different metals, but for different organic materials formed by living tissue. And of course they have to use different reagents to identify the separated compounds. However, the principles remain the same as for your simple experiment above.

The principles of chromatography also can be applied to the VAPOR or GAS phase, instead of liquids. Gas chromatography is a powerful tool for the chemical research worker to separate and identify what compounds might be present in a reaction mixture, for example. It is especially useful in organic chemistry. Chromatography is used extensively also in biology and plant chemistry.

PART II:

Your teacher will have several pieces of minerals left over from your work on a previous Lab Unit. Select one of the minerals, take a small piece of it, and crush it to a powder in your mortar and pestle. Add a few drops of Nitric Acid. After a few minutes withdraw a SMALL PORTION of the liquid, and place it in the center of a piece of filter paper. This will be your sample.

Develop your chromatograph in the same way as in Part I above. When development is finished, dry the paper in ammonia vapor. Then, using the above tests and any others which your teacher might wish to include, add various reagents to identify some of the metals which might be present.

Report your results to your teacher.

LAB UNIT #26: PREPARATION OF ETHYL ALCOHOL

Ethyl alcohol is used in large quantities for the manufacture of antifreeze materials. However, being the only relatively non-poisonous alcohol, it is used also in the extraction and preparation of drug products, in flavors and extracts, perfumes, and hair tonics.

One way of producing this alcohol on a commercial basis is by the fermentation process, starting with sugar. The process requires the presence of a catalyst (zymase) which usually is added in the form of yeast.

Other organic solvents also can be made by fermentation. However, different starting materials would be used.

Take about 30 ml of Molasses and place it in a fairly large flask.

Take about one-half cake of yeast, and break it up. Add warm water and stir until you make a thin paste. Add this to the flask also.

Take a one-hole rubber stopper which will fit into the neck of your flask, and fit into this a U-shaped glass delivery tube. Put this stopper on your flask so that the end of the delivery tube is immersed into a test tube containing some saturated limewater ($Ca(OH)_2$). The limewater should be clear; if not, filter it.

Now set the entire apparatus aside, in an upright position, until fermentation takes place. If you get an opportunity, look at it once in a while. A gas will be given off during the fermentation reaction.

How can you tell whether there is any gas evolved during the reaction? ____

The gas given off is carbon dioxide which reacts with calcium hydroxide (limewater) solution to give a white insoluble precipitate of calcium carbonate. Do you get such a precipitate formed? ________________________________

The reaction taking place in the flask is called fermentation. For your reaction, it can be described by the chemical equation:

$$\underset{\text{SUGAR}}{C_6H_{12}O_6} \xrightarrow[\text{catalyst (zymase)}]{} \underset{\text{ETHYL ALCOHOL}}{2\ C_2H_5OH} - \underset{\text{CARBON DIOXIDE}}{2\ CO_2}$$

While the catalyst is a very necessary part of the above reaction, is it considered to be one of the reactants? ______

2. When the reaction appears fairly complete (several days, usually), disconnect your delivery tube, and instead attach a condenser. (Which way should it flow for best results?) Also, you should have a thermometer inserted in the neck of your flask. This will tell you the boiling point at which any particular fraction of liquid distills over.

When your apparatus is properly assembled (it must be vapor tight), start the water flowing through the condenser, and heat the flask until vapor begins to flow out of the end of the condenser.

After a few drops have formed from the condenser, record the temperature of the distillate: ________° C.

Ethyl alcohol boils at 78.5° (if it is pure).

Continue the distillation until you have distilled off essentially all the alcohol. (You can tell this by watching the temperature of distillation.) You then can disconnect, disassemble, and clean your apparatus.

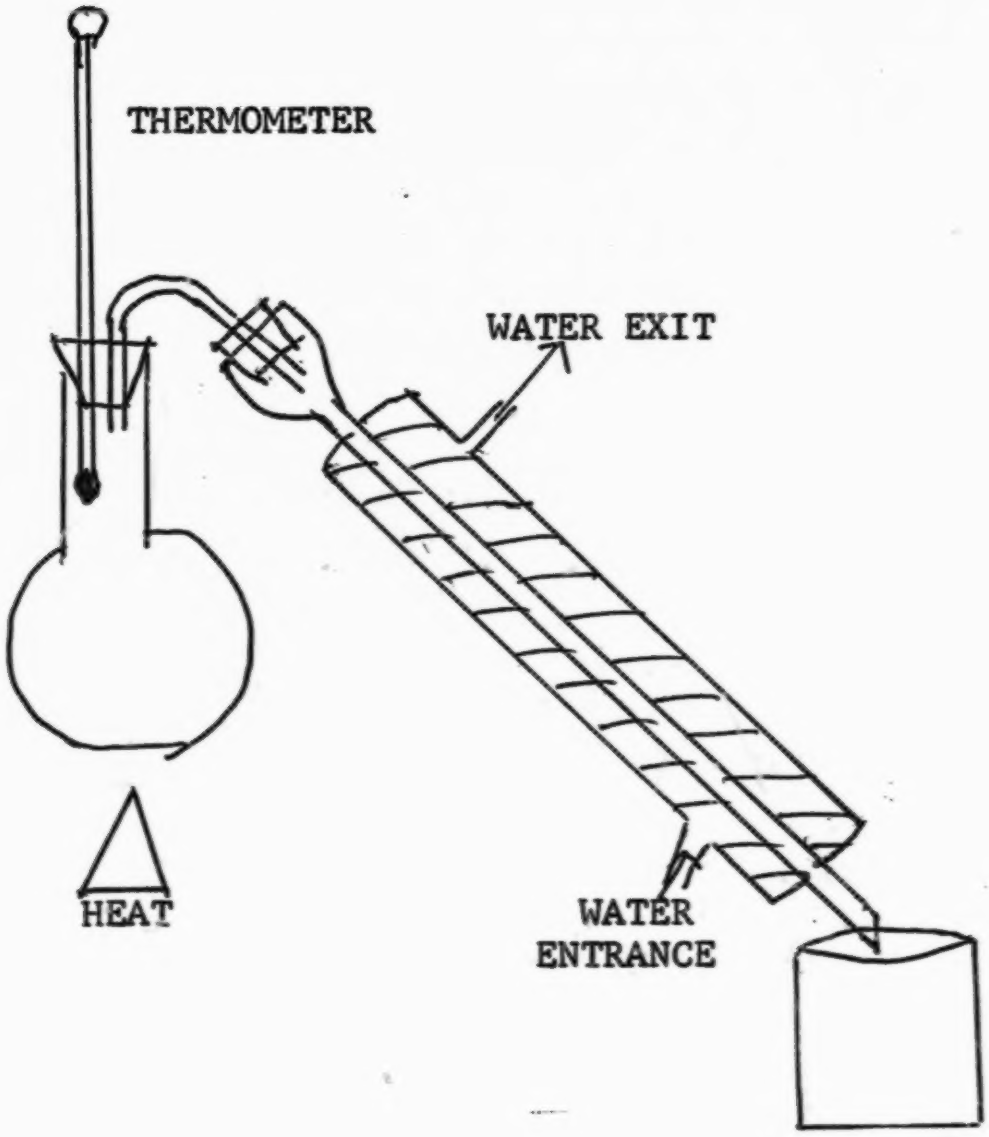
The product you have obtained is fairly pure ethyl alcohol. Put a drop on your skin, and blow across it. What is the sensation? ______________________________

Now taste a few drops. Describe the taste: ____________

Was the alcohol fraction that you collected fairly pure?

____

Your distillation setup should look something like this:


THERMOMETER
WATER EXIT
HEAT
WATER
ENTRANCE

EXAMINER: PLEASE READ THIS TO CLASS PRIOR TO TESTING.

STUDENTS, YOU ARE ABOUT TO TAKE A SPECIAL PRE-TEST ON CHEMISTRY. THE TEST WILL BE ON THE LESSON MATERIAL OF THE SPECIAL COURSE WHICH YOU ARE ABOUT TO TAKE.

THIS PRE-TEST IS TO ESTABLISH THE LEVEL OF ACHIEVEMENT AT WHICH YOU ARE STARTING. THEREFORE, WE DO NOT EXPECT YOU TO BE ABLE TO ANSWER MANY OF THE QUESTIONS CORRECTLY AT THIS TIME, POSSIBLY EVEN NONE.

DON'T LET THIS DISCOURAGE YOU. THE GRADE ON THIS TEST HAS NOTHING TO DO WITH AND NO EFFECT WHATSOEVER ON YOUR FINAL GRADE IN THIS COURSE.

JUST DO THE BEST YOU CAN ON THIS TEST. IF YOU DON'T HAVE ANY IDEA OF THE CORRECT ANSWER, YOU CAN GUESS IF YOU LIKE, OR JUST LEAVE IT BLANK. We would prefer that you just leave it blank if you know absolutely nothing about the question.

This is a multiple-choice examination--only one answer. There are forty questions, and you will have just forty minutes for the test so you have about one minute to spend on each question.

You can mark DIRECTLY on the question sheets. Only ONE answer is right for each question. Draw a circle in HEAVY PENCIL around the letter giving the CORRECT ANSWER.

EXAMPLE: THE COLOR OF THE DAYTIME SKY IS USUALLY:

a) red [✓ b)] blue c) yellow d) purple

Circle the (b) as the correct answer for the example.

ARE THERE ANY QUESTIONS:

Then START.

Time Started: Time Finished:
Date: Examiner:
School: Town:
No. of students:
Experimental _______ or Control _____ group
Grades represented:
Attach student roll of names herewith

Supt.: ____________________________ Principal: ____________________

Science Teacher ____

DO NOT PERMIT STUDENTS TO TAKE A COPY OF THIS EXAM WITH THEM

DATE: ______________________ Name: ____________________

PRE-TEST AND FINAL EXAM ON SPECIAL SCIENCE COURSE FOR NON-SCIENCE HIGH SCHOOL STUDENTS. RESEARCH DEPARTMENT OF WESTERN NEW MEXICO UNIVERSITY, DR. GEORGE WALTON, PROJECT DIRECTOR.

This is a multiple-choice examination--only one answer. There are forty questions, and you will have just forty minutes for the test so you have about one minute to spend on each question.

You can mark DIRECTLY on the question sheets. Only ONE answer is right for each question. Draw a circle in HEAVY PENCIL around the letter giving the CORRECT ANSWER.

EXAMPLE: THE COLOR OF THE DAYTIME SKY IS USUALLY:

a) red [✓ b) blue] c) yellow d) purple

Circle the (b) as the correct answer for the example.

PROBLEM #1:

A reported value is given as 0.00537, implying a degree of confidence of:

a) three significant figures

b) six significant figures

c) one significant figure

d) five significant figures

PROBLEM #2:

If you sit too close to a television set, you may get harmed because of:

a) ultra-violet light rays coming from the set

b) beta rays coming from the set

c) X-rays coming from the set

d) infra-red rays coming from the set

PROBLEM #3:

The metric system is used in scientific measurement work because:

a) it always involves handling smaller numbers.

b) it's a more fashionable system because it came from Europe.

c) it's a decimal system involving units of tens.

d) years ago they made too many meter sticks, and they had to be sold to the schools.

PROBLEM #4:

Chemistry will be very important in the world of the future because:

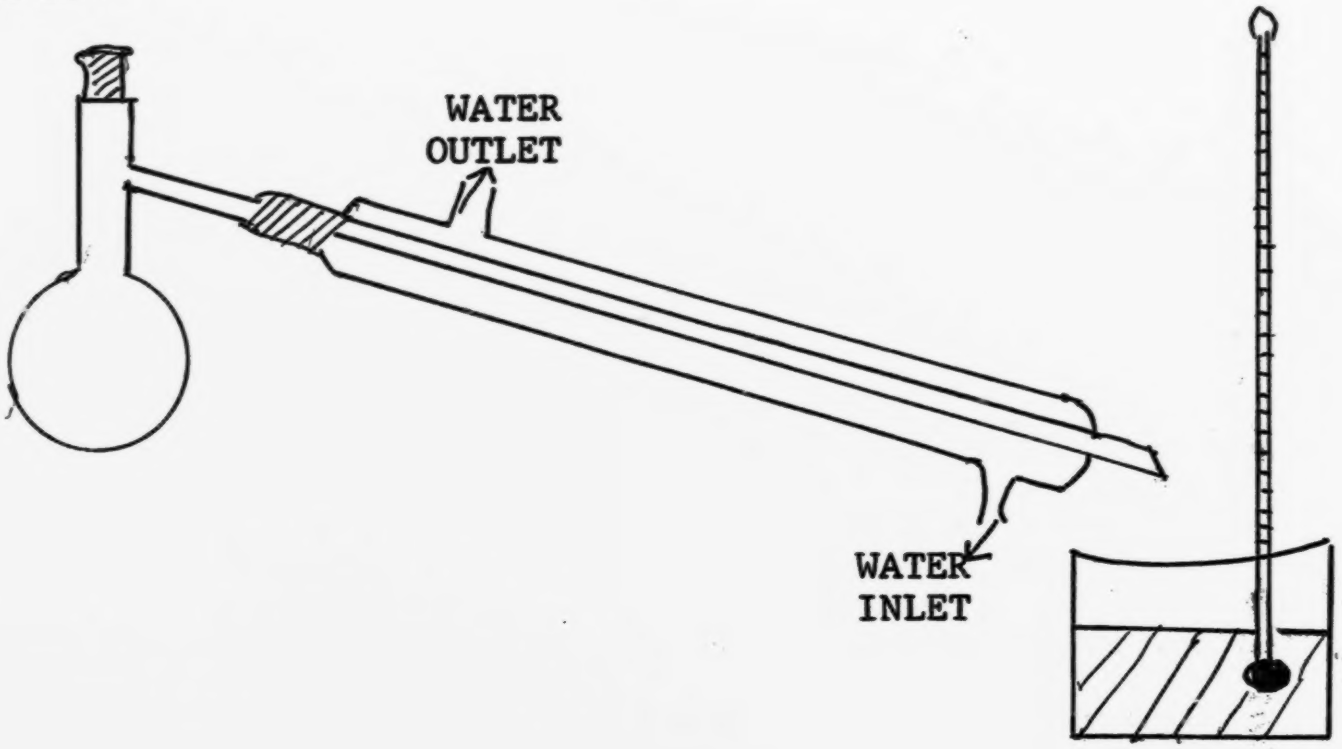
a) it hasn't been very important up to now.

b) it might find a way to prevent the atom bomb from working.

c) it might find a way to change chemical energy into electrical energy.

d) it should provide new sources of food for the increased population.

PROBLEM #5:



This distillation apparatus is set up wrong because:

a) the distilling flask is too large.

b) the angular tip at the delivery end of the condenser should be turned upward.

c) the thermometer should be placed in the distilling flastk.

d) the water should go into the condenser at the top, and out the bottom.

PROBLEM #6:

The "Scientific Method" is:

a) an attitude of mind in approaching a problem.

b) the method used by all scientists.

c) a particular method which will solve all scientific problems.

d) the method used by dentists to fill your teeth.

PROBLEM #7:

If somebody gave you a ring which might be either pure gold or brass, and you wanted to tell the difference without hurting the ring in any way, you could do this by measuring a physical property called:

a) surface tension.

b) magnetism.

c) refractive index.

d) density.

PROBLEM #8:

If you put soap or detergent on a small pond, a duck on the pond would sink because you have changed a physical property called:

a) viscosity

b) density

c) surface tension

d) refractive index

PROBLEM #9:

The rusting of a piece of iron is a chemical property of iron because it shows:

a) how iron can be changed.

b) how one kind of matter can react with another kind of matter to form a material with different physical and chemical properties.

c) that a material with a different color can be formed.

d) that no light nor heat were given off during the change.

PROBLEM #10:

Sulfur in Texas is mined from deep underground. The mining process depends upon a physical change of the sulfur called:

a) melting.

b) boiling.

c) filtering.

d) distilling.

PROBLEM #11:

If you had some water mixed with sand and salt, you could purify the water by:

a) treating it with chlorine and then filtering it.

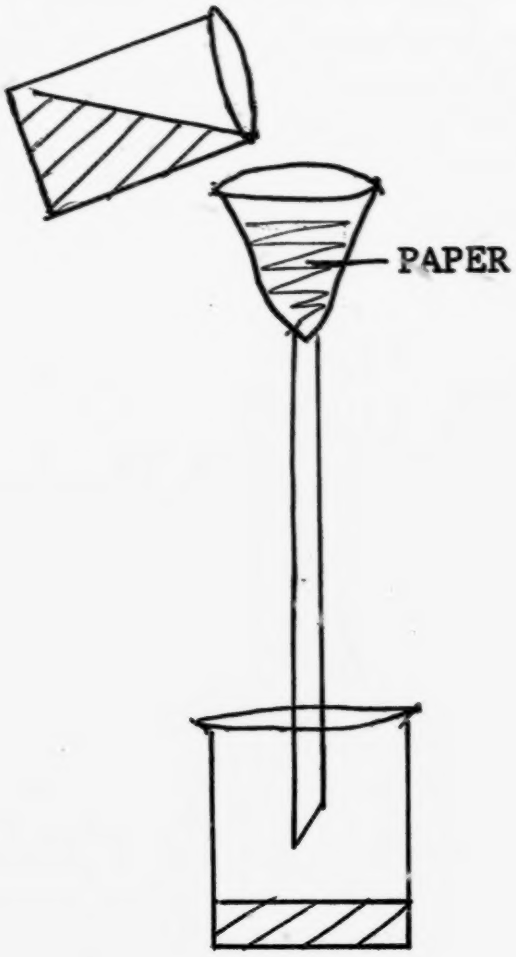
b) filtering the water and then aerating it.

c) adding a water softener.

d) filtering the water and then distilling it.

PROBLEM #12:

The laboratory process shown here is called filtering. It will remove materials which are:



a) dissolved

b) suspended

c) colloidal

d) volatile

PROBLEM #13:

Ammonia gas can be made by the reaction:

$3H_2 + N_2 \dashrightarrow 2NH_3$

When this reaction has reached a condition of equilibrium, the equilibrium can be moved so as to produce more ammonia by:

a) increasing the pressure on the reaction.

b) reducing the pressure on the reaction.

c) taking away some of the hydrogen gas.

d) none of the above.

PROBLEM #14:

Some valuable metal bearing minerals may be separated from associated worthless rock by a process called:

a) the Frasch process.

b) flotation.

c) distillation.

d) neutralization.

PROBLEM #15:

Here is a partial list of metallic elements in the ElectroMotive Series and their Standard Electrode Potentials in volts. Based on this list, which of the following pairs of metals would give the highest voltage in a bimetallic cell:

EMF Series

Potassium	- 2.9 volts
Magnesium	- 2.3 volts
Aluminum	- 1.7 volts
Zinc	- 0.8 volts
Cadmium	- 0.4 volts
Antimony	+ 0.2 volts
Copper	+ 0.4 volts
Silver	+ 0.8 volts
Gold	+ 1.4 volts

a) Potassium and zinc?

b) Aluminum and antimony?

c) Zinc and copper?

d) Magnesium and gold?

PROBLEM #16:

If a child swallowed lye (sodium hydroxide) by mistake, you would help him best by immediately giving him:

a) sulfuric acid

b) water

c) vinegar

d) egg white

PROBLEM #17:

To be effective as a "dry cleaner's soap", a material would have to:

a) be soluble in organic solvents, rather than water.

b) contain potassium, instead of sodium atoms.

c) be soluble only in gasoline.

d) be non-ionic.

PROBLEM #18:

If you take large overdoses of vitamins:

a) you may develop blisters.

b) you won't see as well after dark.

c) you may get a disease called beri-beri.

d) it won't harm you.

PROBLEM #19:

Ammonia is used as a modern fertilizer

a) because it provides a base.

b) even though it is difficult to apply.

c) because it provides hydrogen to the soil.

d) because it provides nitrogen to the soil.

PROBLEM #20:

The destructive distillation of wood yields several useful products including:

a) wood pulp.

b) turpentine.

c) coke.

d) calcium carbonate.

PROBLEM #21:

Butane is an organic compound found in natural gas. It makes a good fuel because:

a) all compounds found in natural gas make good fuels.

b) all organic compounds burn very easily.

c) it already contains oxygen atoms.

d) it contains carbon and hydrogen atoms which can combine with oxygen to give off heat.

PROBLEM #22:

Air is a mixture of gases that contain about:

a) 20 per cent water vapor.

b) 1 per cent oxygen gas.

c) 80 per cent nitrogen gas.

d) 10 per cent hydrogen gas.

PROBLEM #23:

The halogen elements are fluorine, chlorine, bromine, and iodine. They have a lot of properties in common, including the fact that they are all:

a) non-poisonous.

b) colored.

c) gases.

d) used in refrigerators.

PROBLEM #24:

The different metallic elements are all very much alike in physical properties. All of them:

a) have very high densities.

b) have the same color.

c) conduct electricity.

d) are very brittle.

PROBLEM #25:

A solution of sugar or molasses can be changed into ethyl alcohol (ethanol) and carbon dioxide. The process requires a catalyst which is added in the form of:

a) powdered iron metal.

b) lumps of manganese dioxide.

c) finely divided platinum.

d) yeast.

PROBLEM #26:

The spectroscope is a device for:

a) measuring radioactivity.

b) fixing television sets.

c) deflecting radio waves.

d) identifying elements.

PROBLEM #27:

When the base called sodium hydroxide reacts chemically with hydrochloric acid, one of the materials formed is:

a) chloric hydroxide.

b) sodium base.

c) water.

d) sodium hydrochloride.

PROBLEM #28:

An atom is to an element, the same as a molecule is to a:

a) mixture.

b) compound.

c) gas.

d) ion.

PROBLEM #29:

The formula for nitric acid, HNO_3, means that in this compound:

a) one-third of a nitrogen atom would combine with one oxygen atom.

b) it contains three hydrogen, three nitrogen, and three oxygen atoms.

c) three oxygen atoms are combined with one HN atom.

d) three oxygen atoms are combined with one hydrogen atom and one nitrogen atom.

PROBLEM #30:

The total net valence of a chemical compound, like calcium carbonate, $CaCO_3$, always adds up to:

a) zero.

b) a positive number.

c) a negative number.

d) a positive or a negative number.

PROBLEM #31:

Matter can exist in three different physical states: solid, liquid, or gas. To go from one physical state to another always requires:

a) a change in color.

b) a change in chemical properties.

c) a change in particle size.

d) a change in energy.

PROBLEM #32:

The three ways that matter can be changed are: physical change, chemical change, and nuclear change. Nuclear change always involves:

a) only changes in physical properties.

b) only changes in state.

c) changes deep inside the atom.

d) changes in the outer parts of the atom.

PROBLEM #33:

Kinetic-molecular theory tells us that gas molecules:

a) always move at very high speeds regardless of temperature.

b) exert pressure on the walls of their container due to their motion.

c) move faster when the temperature is very low.

d) slow down and finally stop due to collisions with each other.

PROBLEM #34:

If you take two identical milk bottles and fill one with hydrogen gas and one with oxygen gas, Avogadro's Law says that each bottle will contain the same number of gas molecules, but this is true only if:

a) the two bottles were filled under the same conditions of temperature and pressure.

b) the bottle of hydrogen was filled at a much lower temperature than the bottle of oxygen.

c) the bottle of oxygen was filled at a much higher pressure than the bottle of hydrogen.

d) both bottles are at absolute zero temperature.

PROBLEM #35:

If you fill two tires of the same size to exactly the same air pressure, and then put one of them on an auto and run at sixty miles per hour for one hour, the tire on the auto will show a higher pressure because:

a) speed increases your pressure.

b) it got hotter during the ride.

c) the air molecules in the other tire had a chance to slow down and stop.

d) the tire on the car got weaker because of wear.

PROBLEM #36:

An ION is different from an atom because in solution it can:

a) decompose.

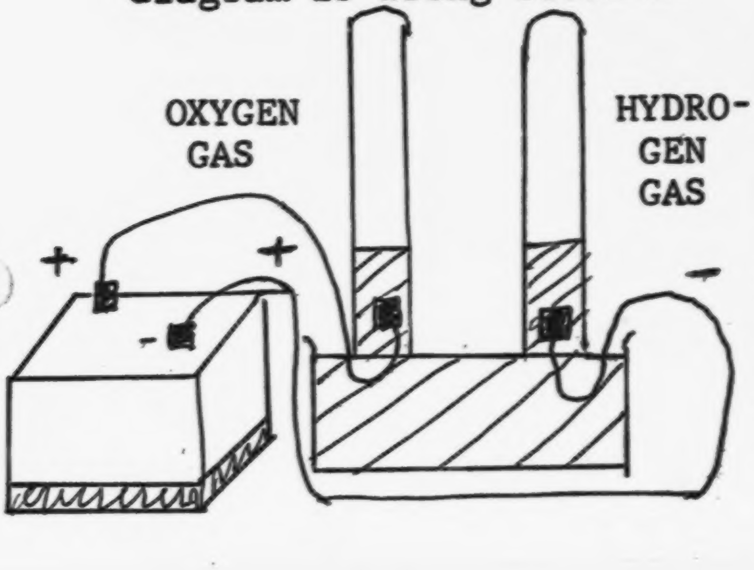
b) conduct electricity.

c) change into iron.

d) neutralize an acid.

PROBLEM #37:

As the diagram shows, a current is being passed from a battery through water containing a few drops of sulfuric acid. The diagram is wrong because:



a) hydrogen gas should be coming off from both electrodes.

b) nothing should take place.

c) oxygen gas should be given off at both electrodes.

d) you should get twice the volume of hydrogen as you get of oxygen.

PROBLEM #38:

Colloidal systems always involve:

a) electrically charged particles.

b) metal particles.

c) particles of a special size range.

d) bright colors.

PROBLEM #39:

We can burn hydrogen in air to give water according to the reaction:

$$2\ H_2 + O_2 \dashrightarrow 2\ H_2O$$

If we start with 4.0 grams of hydrogen, it will always unite with exactly 32.0 grams of oxygen to form just 36.0 grams of water. This is because of:

a) The Law of Multiple Proportions.

b) Avogadro's Law.

c) The Law of Conservation of Mass.

d) Boyle's Law.

PROBLEM #40:

When you have a condition of chemical equilibrium, you have a condition in which:

a) the backward reaction is proceeding exactly as fast as the forward reaction.

b) the system is completely static; there is no motion of any kind in either direction.

c) the reaction refuses to go any further because it is tired.

d) you can form only so much of a certain reaction product.

SPECIAL CHEMISTRY COURSE: SEMESTER I--Six Weeks Test

This is a true or false test. Put either T or F in the answer space. You will have 50 minutes for 50 questions.

________ 1. The knowledge and skills you get from a study of chemistry may help you get or hold a better job.

________ 2. The gram is a unit of length in the metric system.

________ 3. The main use of a scientific "model", such as a model of the atom, is to help us visualize abstract concepts.

________ 4. By the physical property called density we can tell whether an object is made out of lead, or out of aluminum metal.

________ 5. By the physical property called magnetism we can tell whether an object is made out of brass or gold.

________ 6. Emotion and intuition play a large part in working on problems by the scientific method.

________ 7. A needle may float on water due to a physical property called surface tension.

________ 8. When you buy oil for an auto engine, you specify a number which relates to its viscosity.

________ 9. The basic unit of time in the metric system is called the microsecond.

________ 10. To measure the speed of an object, we would need to measure the distance it moves and its acceleration.

________ 11. To measure the density of an object, we would need to measure its weight and the volume it occupies.

________ 12. The Fahrenheit thermometer is used most in scientific work.

________ 13. On the Centigrade temperature scale, the boiling point of water reads 0.0 degrees.

________ 14. The Absolute temperature scale is used mostly for scientific work dealing with gases.

________ 15. 32 degrees Fahrenheit is the same temperature as +273° Absolute.

________ 16. When properly used, the number of significant figures tells us how valid or trustworthy an experimental result is.

________ 17. The number 0.00105 has five significant figures.

________ 18. Considering significant figures, the product of multiphying 2.3 times 0.41 should be reported as 0.94.

________ 19. The distance from the earth to the sun, given as 93,000,000 miles, is only valid to two significant figures.

________ 20. A molecule is the smallest particle of an element.

________ 21. An atom is the smallest particle which would exhibit the properties of a particular compound.

________ 22. Molecules always contain atoms.

________ 23. Atoms always contain molecules.

________ 24. Atoms combine to make molecules.

________ 25. Mixtures do not have any definite composition.

________ 26. Mixtures have different chemical properties from their original materials.

________ 27. Mixtures cannot be separated into their original materials by mechanical methods.

________ 28. The physical properties of a mixture of two materials A and B will lie somewhere in between the separate physical properties of A and B.

________ 29. A compound always has a definite composition by weight.

________ 30. The physical properties of a compound AB will lie somewhere in between the physical properties of the element A and B.

________ 31. An ion is a charged atom.

________ 32. The physical properties of a compound may be quite different from the physical properties of the elements which form it.

________ 33. A compound can be separated into its component elements by mechanical methods.

________ 34. Solubility is a chemical property.

________ 35. The physical property which measures the ability of a material to carry or transmit electricity is called conductivity.

________ 36. Surface tension is a physical property which is important in washing dishes.

________ 37. You can get a bad burn from steam because water has a high value for a physical property called heat of vaporization.

________ 38. Chemical properties are frequently used as the basis of non-destructive testing in the control of industrial processes.

________ 39. In general, it is true that the elements with the heavier atomic weights have a greater density.

________ 40. The physical property of X-rays which makes them useful to doctors is called refractive index.

________ 41. The fact that hydrogen can combine with oxygen to produce water is a chemical property of hydrogen.

________ 42. The combining of iron with oxygen to form rust is a chemical property of iron.

________ 43. A change of energy is not involved in going from one state of matter to another.

________ 44. The mining of sulfur in Texas is based on a change in state of the sulfur.

________ 45. The water coolers that are used for air conditioning in New Mexico depend upon the chemical properties of water.

________ 46. Some materials can be separated from each other by their differences in solubility.

________ 47. Most metals will not conduct electricity.

________ 48. Graphite is the hardest substance known.

________ 49. All elements and compounds can exist in all three states of matter.

________ 50. To be useful in making wire, a metal would have to be quite ductile.

SPECIAL CHEMISTRY COURSE: SEMESTER I--Twelve Weeks Test

This is a true or false test. Put either T or F in the answer space. You will have 50 minutes for 50 questions.

_______ 1. Chemical change results in the formation of a material or materials with different physical properties only.

_______ 2. Chemical change is responsible for many everyday processes such as digesting food, using a flashlight, and driving an auto.

_______ 3. A change of state, such as from ice to liquid water, involves a chemical change.

_______ 4. A chemical change always involves a change in energy of the system.

_______ 5. A chemical change can sometimes involve a fraction of an atom such as half an atom or one-third of an atom.

_______ 6. Chemical change usually involves complicated ratios of whole numbers between the different kinds of atoms. For example, 123 atoms of X might react with 81 atoms of Y to form a compound.

_______ 7. The physical properties of a mixture will be different from the physical properties of the original components.

_______ 8. Chemical changes may result in the formation of new elements.

_______ 9. Nuclear changes are associated with very large changes in energy of the system.

_______ 10. Chemical change always involves atoms in definite ratios by small whole numbers.

_______ 11. Nuclear changes do not presently have much effect on our daily way of life.

_______ 12. Much nuclear research is being carried out at present.

_______ 13. An atom bomb, when it goes off, is an example of a nuclear reaction.

_______ 14. Ordinary explosives, like dynamite, involve only the outermost parts of the atom (not the nucleus).

________ 15. The rusting of iron is not counted as a chemical reaction because it is too slow.

________ 16. Nuclear changes may result in the formation of new elements.

________ 17. Most chemical changes (reactions) go slower at high temperatures.

________ 18. We keep our food in refrigerators because it develops a better taste at lower temperatures.

________ 19. The Pasteurization of milk involves both high and low temperatures.

________ 20. A catalyst may change the speed of a reaction, but is itself used up during the reaction.

________ 21. Catalysts may be used either to speed up or slow down a chemical reaction.

________ 22. Temperature and catalysis are two ways of changing the speed of a chemical reaction.

________ 23. C, O, H, and N are the chemical symbols for carbon, oxygen, hydrogen, and nitrogen.

________ 24. P, Al, Zn, and Ca are the chemical symbols for phosphorous, aluminum, zinc, and carbon.

________ 25. The Law of the Conservation of Mass applies to all chemicals and nuclear reactions.

________ 26. The equation for the rusting of iron in air, and the relative atomic weights, can be written:

$$\text{Fe}\ (56.0) + \text{O}\ (16.0) \dashrightarrow \text{FeO}\ (X)$$

in which case the value of X will equal 72.0.

________ 27. The equation for the burning of hydrogen in oxygen to give water can be written:

$$2H_2 + O_2 \dashrightarrow 2H_2O + 119{,}200 \text{ calories}$$

and shows that heat energy is evolved during the reaction.

________ 28. If the reaction of iron and oxygen gives off heat, then the reaction in which iron oxide is broken down to form iron metal and oxygen takes up heat.

________ 29. One molecule of phosphoric acid, H_3PO_4, contains three hydrogen atoms, one oxygen atom, and four phosphorous atoms.

________ 30. A piece of iron will be lighter after it becomes rusty.

________ 31. All atoms are made from the same "building blocks"--protons, neutrons, and electrons.

________ 32. Knowledge regarding the structure of the atom has been acquired slowly but steadily over hundreds of years.

________ 33. Intimate and correct knowledge of the structure of the atom dates back to the time of the Greek philosophers.

________ 34. Intimate and correct knowledge of the structure of the atom started with the use of the experimental method in science.

________ 35. The structure of an atom, from experimental evidence, is similar to a midget "solar system".

________ 36. Material substance, as we know it, can actually be destroyed and vanish in nuclear reactions.

________ 37. Nuclear reactions involve much greater changes in energy than ordinary chemical reactions.

________ 38. Atoms of one particular element are all alike.

________ 39. The atoms of different elements have different numbers of protons, neutrons, and electrons.

________ 40. Lithium is the lightest of all elements.

________ 41. Atoms can combine together to form molecules.

________ 42. Molecules can combine together to form atoms.

________ 43. An atom which has lost or gained an electron is called a radical.

________ 44. A neutral atom dissolved in water will not carry an electrical charge.

________ 45. Electrons weigh much more than protons.

________ 46. Electrons carry a negative charge.

________ 47. All of the substances in the world are made up of about only one hundred different elements.

________ 48. The Periodic Table arranges the elements in their alphabetical order for easy reference.

________ 49. The symbol Na^+ is the symbol for the sodium ion.

________ 50. Atoms are always electrically neutral unless they gain or lose electrons.

SPECIAL CHEMISTRY COURSE: SEMESTER I MID-TERM EXAM

This is a TRUE or FALSE test. Circle either T or F in the answer space. You will have 50 minutes for 50 questions.

T. F. 1. In iron oxide (FeO) the valence of the iron atom is plus one.

T. F. 2. In sulfuric acid (H_2SO_4) the valence of the sulfur atom is plus six.

T. F. 3. The nitrogen atom in ammonia (NH_3) has a different valence from the nitrogen atom in nitric acid (HNO_3).

T. F. 4. The formula for zinc sulfate ($ZnSO_4$) tells us that each molecule contains one zinc atom, one sulfur atom, and four oxygen atoms.

T. F. 5. The formula for lead carbonate ($PbCO_3$) tells us that each molecule contains one lead atom and one carbonate atom.

T. F. 6. The elements sodium (Na), silver (Ag), and zinc (Zn) frequently display more than one valence in their different compounds.

T. F. 7. The elements chlorine (Cl), nitrogen (N), and sulfur (S) frequently display more than one valence in their different compounds.

T. F. 8. The forces which hold together similar atoms to form a molecule like O_2 are different from the forces that hold together unlike atoms to form a molecule like HNO_3.

T. F. 9. The total negative and positive valence of the atoms in a compound usually adds up to plus one.

T. F. 10. A proper chemical formula, like H_3PO_4, tells us what kinds of atoms are present and how many of each.

T. F. 11. Valence is a chemical property which determines the manner in which atoms combine with each other.

T. F. 12. The process of mining sulfur in Texas involves a change of state of the sulfur.

T. F. 13. Wyoming may become an important producer of sulfur from petroleum.

T. F. 14. Sulfur is a very inactive element, and will combine with very few other elements.

T. F. 15. Sulfur can burn in air to give a compound called hydrogen sulfide.

T. F. 16. Sulfur dioxide is used to bleach and preserve dried fruits such as raisins and apricots.

T. F. 17. Sulfuric acid is formed by dissolving sulfur dioxide in water.

T. F. 18. The production and use of sulfuric acid in a country is closely related to its industrial growth and civilization.

T. F. 19. Sulfuric acid will burn your skin badly because it is a very effective "dehydration agent".

T. F. 20. If you get sulfuric acid on your skin, the most effective treatment is to send for a doctor.

T. F. 21. In general, acid burns on skin or clothing should be treated by rolling on the floor.

T. F. 22. Sulfuric acid is very useful in organic chemistry because it is a source of sulfur in many reactions.

T. F. 23. Hydrogen sulfide, the "rotten egg" odor, is good for practical jokes because it is not very poisonous.

T. F. 24. Sulfur is a typical "non-metal".

T. F. 25. Sulfur is among the five most abundant elements in the earth's crust.

T. F. 26. In general, non-metals are brittle and do not conduct electricity.

T. F. 27. Air is a compound containing oxygen and nitrogen plus some other gases.

T. F. 28. Because air is a gas, it cannot carry any suspended solid materials in it.

T. F. 29. Air is composed mostly of nitrogen gas.

T. F. 30. Oxygen is our most abundant element.

T. F. 31. A very fast oxidation reaction, accompanied by heat, light, and physical shock, is called an explosion.

T. F. 32. Food spoilage involves oxidation processes and the presence of bacteria and moisture.

T. F. 33. The spontaneous combustion of turpentine-containing rags involves bacterial action.

T. F. 34. A gasoline fire can usually be put out easily with water.

T. F. 35. In case of a clothing fire, the victim should be put into a horizontal position immediately to prevent the breathing of flame into the lungs.

T. F. 36. A small fire is best handled by running away and calling the fire department.

T. F. 37. A combustible material cannot burn or explode if it is suspended in air in the form of very fine particles.

T. F. 38. Welding and cutting torches use pure oxygen because the combustion reaction goes faster and provides a higher temperature.

T. F. 39. Baking soda is an effective, cheap, and easily available material for putting out fires.

T. F. 40. Oxygen can be produced in the laboratory by heating certain compounds containing oxygen, or by passing an electric current through water containing some ionic substance.

T. F. 41. Commercially, large quantities of oxygen are obtained from the decomposition of mercuric oxide.

T. F. 42. The diver's sickness called the "bends" is related to oxygen dissolving in the blood under high pressure.

T. F. 43. One liter of air at 20° C can hold 17.2 mg of water vapor. If it actually contains only 8.6 mg, this air has a "relative humidity" of 50%.

T. F. 44. An "evaporative cooler" type of air conditioner would not work very well in San Diego or Los Angeles since these cities are on the ocean.

T. F. 45. Air friction has little or no effect on the temperature of rocket re-entry because the re-entry vehicle is moving too fast.

T. F. 46. If we could get to Absolute Zero degrees, even then a gas would still occupy a small but finite volume.

T. F. 47. A tire may blow out from fast driving because the air molecules in it develop a faster average speed resulting in a raise in temperature and pressure.

T. F. 48. The volume of a given amount of gas will vary directly with its pressure.

T. F. 49. If we release a balloon filled with a gas that is lighter than air, the higher it goes in the atmosphere, the larger it will get.

T. F. 50. The volume of a given amount of gas will vary directly with its temperature in degrees Centigrade.

SPECIAL CHEMISTRY COURSE: SEMESTER II--Six Weeks Test

This is a multiple-choice test. Only one answer is correct for each question. Circle the correct answer. You will have 50 minutes for 25 questions.

1. Pure water:
   a. wets all other substances very readily.
   b. conducts electricity quite well.
   c. covers 75% of the earth's surface.
   d. can be made by burning pure hydrogen gas in pure oxygen gas.

2. "Heavy" water:
   a. is water containing a high ratio of the isotopes deuterium or tritium.
   b. is water that contains lead salts.
   c. is water that has been cooled below its freezing point.
   d. is water that contains over 23% of solute.

3. The "Heat of Fusion" is:
   a. the amount of heat energy required to distill one gram of water.
   b. the amount of heat energy required to change one gram of ice into one gram of water.
   c. the reason why steam can give you a bad burn.
   d. the amount of heat energy required to fuse a pound of ice.

4. Water is one of the products formed by:
   a. all nuclear reactions.
   b. all neutralization reactions.
   c. all decomposition reactions.
   d. all electrolytic reactions.

5. Water can be separated from a non-volatile solute by:
   a. filtration.
   b. aeration.
   c. centrifugation.
   d. distillation.

6. When you boil water, bubbles of air appear. This is because:
   a. gases are less soluble in liquids at higher temperatures.
   b. boiling water attracts air bubbles from the atmosphere.
   c. at boiling temperatures, water breaks down into air which then escapes.
   d. convection currents caused by boiling process separate air from water.

7. A colloidal system in which the colloid particles are positively charged:
   - a. may be removed by filtering through paper.
   - b. will give you a shock if you dip your finger in it.
   - c. may be precipitated by neutralizing the positive charge.
   - d. can act as a battery.

8. The color of a colloidal system depends primarily upon:
   - a. the average particle size of the dispersed particles.
   - b. the particular size of the dispersed particles.
   - c. the solvent.
   - d. the electrical charge of the particle.

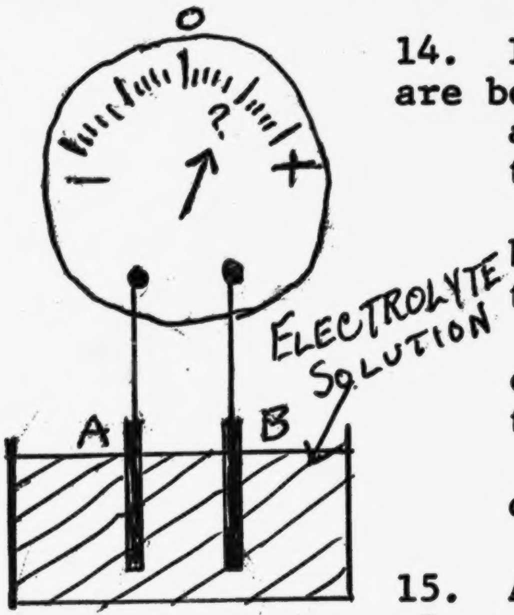
9. Permanganate ion (MnO_4^-) has a deep purple color in water solution. If we were to make a one molar solution of each of the following compounds, which would show the deepest color?
   - a. $NaMnO_4$ (sodium permanganate)
   - b. $MnCl_2$ (manganous chloride)
   - c. $KMnO_4$ (potassium permanganate)
   - d. $Ca(MnO_4)_2$ (calcium permanganate)

10. Chlorine dissolved in water could best be removed by:
    - a. centrifugation.
    - b. diffusion.
    - c. filtration.
    - d. aeration.

11. A change in heat energy is not involved in:
    - a. changing liquid water to ice.
    - b. reacting zinc with sulfuric acid.
    - c. mixing sand and water.
    - d. putting sodium hydroxide into solution.

12. The heat from the sun reaches the earth by a process called:
    - a. insulation.
    - b. radiation.
    - c. calorimetry.
    - d. evaporative cooling.

13. Gas is preferred as a fuel for heating homes because it:
    - a. is non-toxic itself.
    - b. cannot explode.
    - c. gives off non-toxic fumes.
    - d. creates no waste disposal problem.


0
?
−
+
A
B
ELECTROLYTE SOLUTION

14. In this diagram, if electrodes A and B are both made of copper metal:

a. the galvanometer needle will point to zero.

b. the galvanometer needle will go to the minus side.

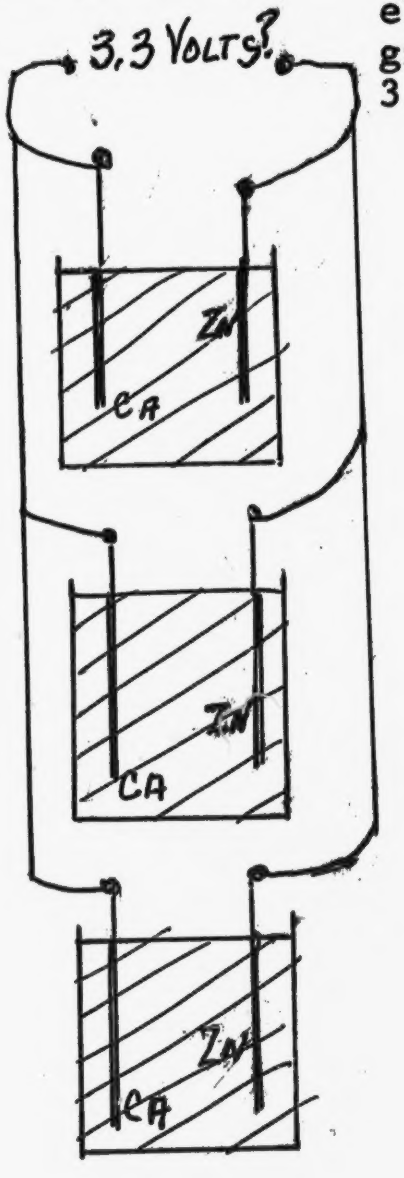
c. the galvanometer needle will go to the plus side.

d. none of these statements are true.

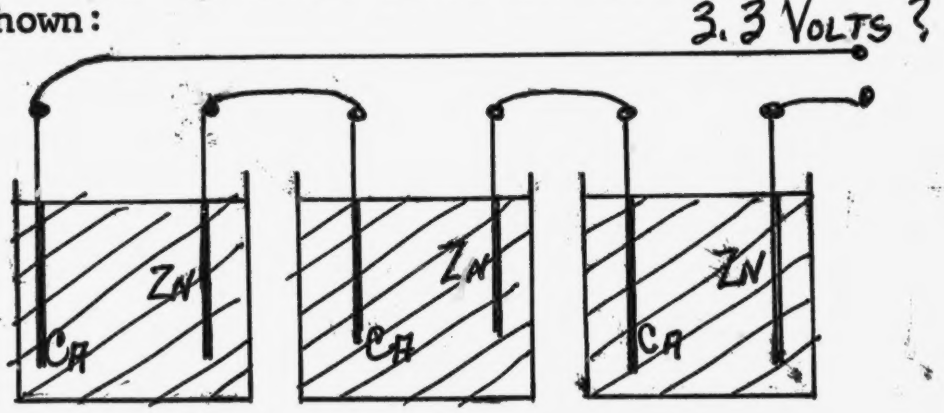
15. A cell using a copper electrode and a zinc electrode immersed in an electrolyte solution gives 1.1 volts. If we wanted a voltage of 3.3 volts, we could:

a. triple the strength of the electrolyte solution.

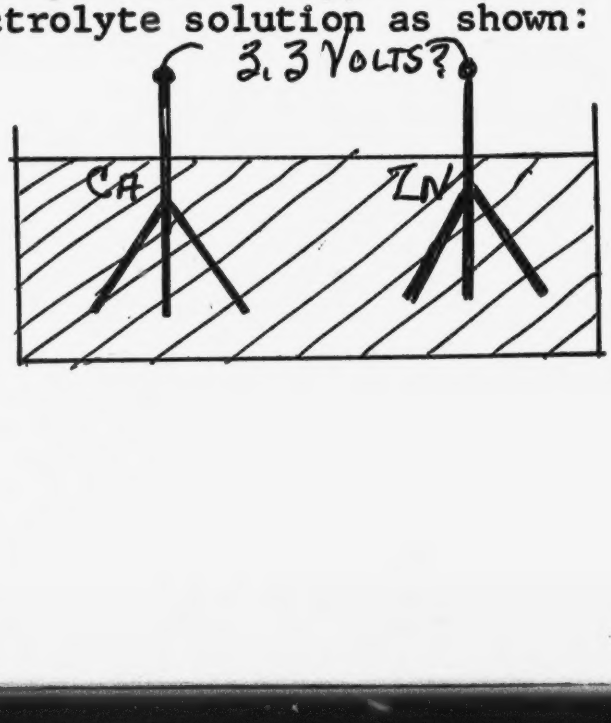
b. hook up three cells in parallel, as shown here.


3.3 VOLTS?
Zn
Cu
Zn
Cu
Zn
Cu

c. hook up three cells in series, as shown:


3.3 VOLTS?
Cu
Zn
Cu
Zn
Cu
Zn

d. hook up three piece of zinc, and three pieces of copper in the same electrolyte solution as shown:


3.3 VOLTS?
Cu
Zn

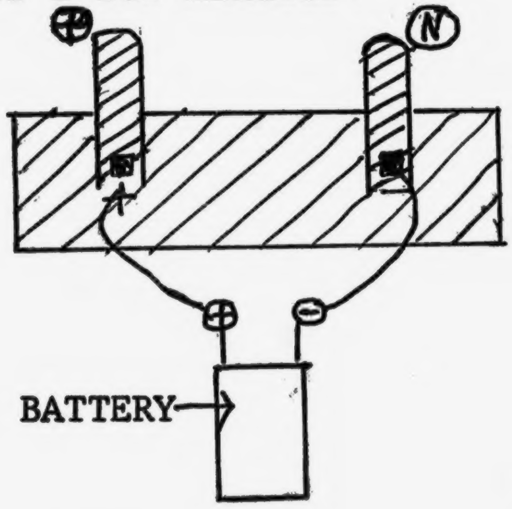
16. EMF Series

Au^{+++}	Ag^{+}	H^{+}	Pb^{++}	Ni^{++}	Zn^{++}	Al^{+++}	Mg^{++}	Li^{+}	
-1.42	-0.80	±0.00	+0.13	+0.25	+0.76	+1.67	+2.34	+3.00	+

A chemical cell made using Magnesium and Aluminum electrodes would give a higher voltage than a cell made using electrodes of:

- a. lithium/aluminum.
- b. zinc/nickel.
- c. magnesium/gold.
- d. lead/silver.

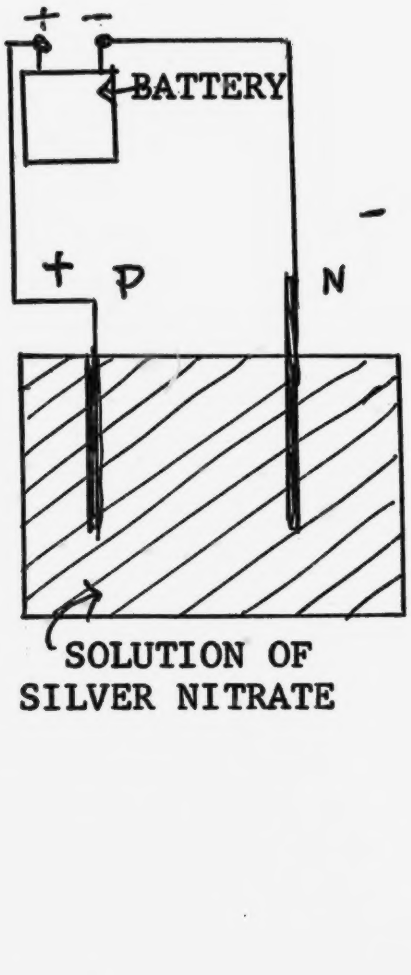
17. As the diagram shows, a current is being passed from a battery through water containing a few drops of sulfuric acid. After a few minutes:



a. the tube at the negative electrode (N) will collect twice as much gas as tube (P).
b. water will form at electrode (P).
c. both tubes will contain the same amount of gas.
d. nothing will take place.

18. As shown, current from a battery is being passed through two metal electrodes (P) and (N) and a solution of silver nitrate. After about an hour:

a. the metal strip (N) will have gained weight.
b. hydrogen gas will be given off at the positive electrode (P).
c. nothing has taken place.
d. the metal strip (P) will have changed color.



SOLUTION OF SILVER NITRATE

19. Which of the following materials, compared on a weight-for-weight basis, would make the most efficient anti-freeze solute?

  a. NaCl (molecular weight-58.5)
  b. NaOH (molecular weight-40.0)
  c. Sugar (molecular weight-342)
  d. NH_4OH (molecular weight-35.0)

20. Which of the following, all factors being considered, would make the most practical anti-freeze solute?

  a. Sulfuric Acid (H_2SO_4)
  b. Gold Chloride ($AuCl_3$)
  c. Sugar ($C_{12}H_{22}O_{11}$)
  d. Sodium Hydroxide (NaOH)

21. Of the following compounds, if one mole (gram-molecular-weight) of each were dissolved in 100 ml of water and the solution raised to its boiling point, which could give you the worst burn?

  a. Acetic Acid (CH_3COOH)
  b. Sugar ($C_{12}H_{22}O_{11}$)
  c. Carbon Dioxide Gas (CO_2)
  d. Sodium Phosphate (Na_3PO_4)

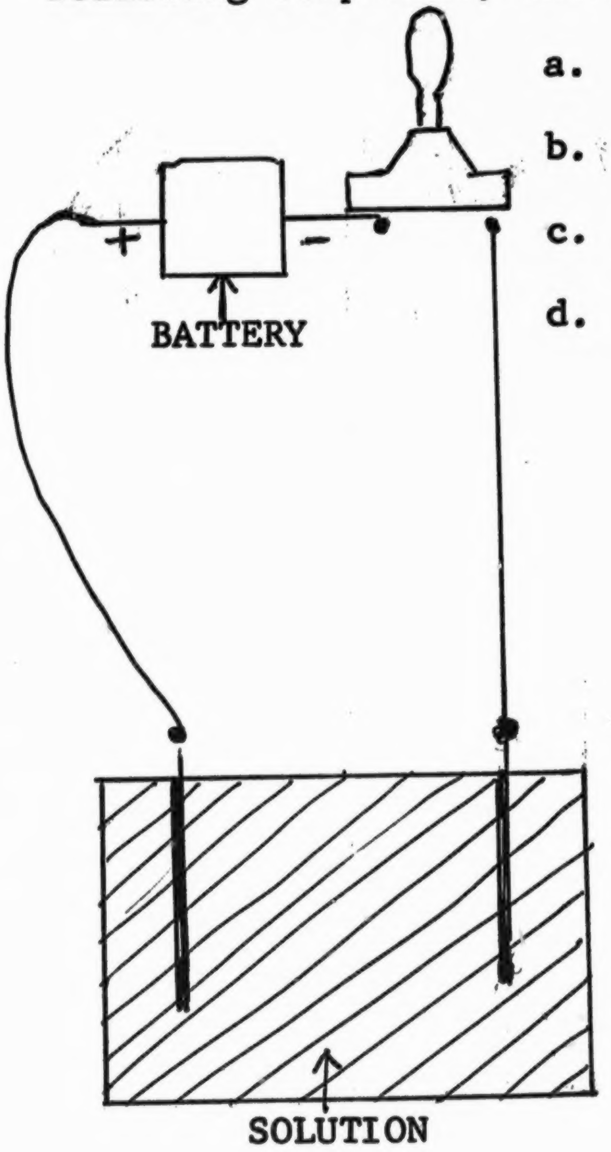
22. If one gram of each of the following compounds were mixed into 100 ml of water, which would have the lowest freezing point?

  a. Calcium Chloride ($CaCl_2$) (molecular weight-111)
  b. Sugar ($C_{12}H_{22}O_{11}$) (molecular weight-342)
  c. Sand (SiO_2) (molecular weight-60)
  d. Ferric Hydroxide ($Fe(OH)_3$) in colloidal form (molecular weight-107)

23. The ability of a liquid to "wet" a solid particle is related to a physical property called:

  a. refractive index.
  b. surface tension.
  c. density.
  d. viscosity.

24. If a battery and bulb were connected as in the diagram, and the beaker contained a Molar solution of one of the following compounds, which would give the brightest light?



a. Sugar ($C_{12}H_{22}O_{11}$)

b. Sulfuric Acid (H_2SO_4)

c. Phosphoric Acid (H_3PO_4)

d. Ammonium Chloride (NH_4Cl)

25. The Eutectic Point of an alloy is:
a. a temperature higher than the melting point of either metal.
b. a temperature halfway between the melting point of either metal.
c. a temperature lower than the melting point of either metal
d. none of these.

SPECIAL CHEMISTRY COURSE: SEMESTER II TWELVE WEEKS' TEST

This is a multiple-choice test. Only one answer is correct for each question. Circle the correct answer. There are 25 questions.

1. In the electromagnetic spectrum the main difference between one type of radiation and another is the:

a. speed b. color c. physical nature
d. wavelength

2. The sun's light and the sun's heat both come to the earth:

a. at the same speed.
b. at different speeds.
c. at speeds which depend upon the earth's gravitational field.
d. at speeds which depend upon the sun's gravitational field.

3. X-rays used in surgery are similar to:

a. ultraviolet waves.
b. infrared waves.
c. gamma rays.
d. radio waves.

4. An instrument called the spectroscope can tell us what elements are present:

a. on the moon.
b. on the planets.
c. on the sun.
d. in the center of our earth.

5. Of the several different kinds of rays given off by the element Radium, the only one which belongs to the electromagnetic spectrum is the:

a. alpha ray.
b. radio ray.
c. beta ray.
d. gamma ray.

6. The use of X-rays or radioactive materials in the treatment of cancer is based on the principle that their rays:

a. kill off only the diseased tissue.
b. kill off both diseased and healthy tissue, but the diseased tissue is killed faster.
c. don't kill any tissue, but convert diseased tissue directly to healthy tissue.

d. neither kill nor heal any tissue, but make the patient feel better.

7. Radioactive isotopes of the proper kind can be used directly in the body:

a. to provide extra energy.
b. to study the body's chemical reactions.
c. to correct heart deficiencies.
d. to make the body resistant to radiation.

8. Mined ore may be upgraded in quality by a process called:

a. flotation.
b. distillation.
c. aeration.
d. filtration.

9. If you were mining a very large deposit of ore, the most economical way probably would be by:

a. cutting tunnels.
b. cutting shafts.
c. cutting both tunnels and shafts.
d. open pit.

10. The metals usually found in the free, or elementary, state in nature are called the:

a. alkali metals.
b. noble metals.
c. alkaline earth metals.
d. transition metals.

11. The most important, or major, elements required for plant growth include:

a. sodium.
b. nitrogen.
c. tungsten.
d. aluminum.

12. Hydroponics is the science of:

a. submarine warfare.
b. water-skiing with small pontoons.
c. growing plants in nutrient solutions.
d. growing plants without water.

13. In recent years most of the nitrogen-containing fertilizers are made using nitrogen:

a. from the air.
b. from Chile.
c. from ocean water.
d. from soybean oil.

14. Trace elements necessary to plant growth and removed from the soil by successive plant crops are replaced:

a. automatically from the air.
b. by excessive watering programs.
c. by using the usual synthetic fertilizers.
d. on the basis of a special program to fit the need.

15. The more civilized the country, the less of its "wood harvest" is used for:

a. construction b. paper c. fuel d. fibers

16. A "sandwich" of thin layers of wood glued together is called:

a. pulpwood b. plywood c. whole wood d. prestwood

17. The distillation of oleoresin from the southern yellow pine tree yields:

a. turpentine b. charcoal c. cellulose d. lignin

18. That part of the paper making process which dissolves out the bonding material holding the wood fibers together is called:

a. "maceration".
b. "beating".
c. "digestion".
d. "impregnation".

19. "Unwoven cloth" is made on a:

a. loom b. weaving machine c. spindle
d. paper making machine

20. The least reactive of the following Halogens is:

a. Fluorine b. Chlorine c. Bromine d. Iodine

21. The only one of the following Halogens which is a gas at room temperature is:

a. Chlorine b. Bromine c. Iodine d. Astatine

22. Moist Chlorine gas is an effective bleaching agent because of the formation of:

a. Hydrochloric Acid b. Hypochlorous Acid
c. Chloric Acid d. Perchloric Acid

23. The use of poison gas in warfare is not considered completely desirable due to the fact that:

a. it maims rather than outright kills soldiers.
b. it is frowned on by the Geneva Convention.
c. it is hard to make.
d. it is difficult to control.

24. The use of Carbon Tetrachloride as a solvent and in fire extinguishers is limited because it is:

a. very expensive.
b. very toxic.
c. very heavy.
d. very rare.

25. The element Bromine is obtained from concentrated sea water or deep well salt brines by:

a. treatment with elementary Chlorine which will displace the Bromine from its compounds.
b. aeration.
c. electrolysis.
d. treatment with elementary Hydrogen which will displace the Bromine from its compounds.

APPENDIX D

PRE-TEST SCORES

Experimental Group

Student Identification No.	Special Chemistry	Anderson-Fisk Chemistry	Reading		Differential Aptitudes		
			Vocabulary	Comprehension	Verbal Reasoning	Numerical Ability	Abstract Reasoning
1	17	14	18	34	21	14	18
2	27	8	49	56	43	26	47
3	22	16	28	34	30	32	38
4	9	9	17	10	15	11	29
5	12	13	7	18	10	16	17
6	17	8	21	38	36	24	45
7	17	11	23	24	22	9	19
8	17	16	17	22	20	22	37
9	20	11	13	22	11	25	38
10	15	12	27	34	30	25	25
11	18	10	28	38	23	23	25
12	17	4	31	32	31	33	38
13	15	17	22	26	21	22	23
14	12	17	21	28	22	15	30
15	16	9	25	22	20	23	33
16	17	11	7	0	18	14	15
17	19	10	11	22	22	20	21
18	12	9	17	14	12	22	13
19	19	5	14	32	32	27	36
20	25	9	38	34	41	24	36

Control Group

Student Identification No.	Special Chemistry	Anderson-Fisk Chemistry	Vocabulary	Comprehension	Verbal Reasoning	Numerical Ability	Abstract Reasoning
21	15	14	35	36	31	26	30
22	20	15	33	40	40	30	41
23	19	15	31	40	35	21	37
24	15	13	18	20	28	12	12
26	21	20	73	54	46	36	41
27	10	20	11	20	17	22	29
28	18	14	30	36	23	26	25
29	18	17	18	28	31	17	25
30	22	13	35	46	24	17	35
31	17	13	20	28	24	23	34
33	16	15	15	28	24	27	29
34	14	22	25	34	25	14	27
35	13	6	17	24	21	29	25
37	24	20	42	42	41	37	44

38	22	18	51	58	37	28	43
39	22	20	23	40	35	30	29
41	18	16	46	52	31	22	38
42	28	18	36	50	31	17	37
43	28	16	50	48	39	40	42
44	14	12	36	48	31	36	31
45	12	13	28	44	37	17	44
46	9	11	36	34	30	19	33
47	20	17	39	48	23	19	41
48	15	14	62	66	42	24	42
49	21	20	54	56	44	27	37
50	15	6	34	48	39	33	29
51	13	19	32	38	26	29	30
52	21	17	24	32	27	21	35
53	14	7	12	30	12	25	34
54	12	15	21	20	13	17	11
55	19	16	27	38	20	23	28
56	18	11	32	20	17	20	21
57	15	18	35	52	34	19	36
58	21	12	21	36	39	36	40
59	16	18	51	54	38	34	37
60	22	9	42	44	43	18	35
61	19	20	34	34	36	31	24
62	23	20	23	20	20	18	24
63	28	26	27	32	33	44	45
64	20	16	12	18	12	20	34
65	17	8	14	12	27	26	37
66	24	13	22	40	27	38	38
67	16	10	22	20	23	18	28
68	21	9	18	38	30	22	23
69	22	7	42	44	33	36	36
70	20	17	35	32	30	24	36
71	21	12	41	40	36	34	39
72	13	15	22	24	20	23	36
73	21	3	28	24	21	19	26
74	20	17	25	36	25	25	27
75	19	9	27	26	26	23	25
76	30	15	16	24	17	23	29

APPENDIX E

POST-TEST SCORES

Experimental Group

Student Identification Number	Special Chemistry	Anderson-Fisk Chemistry	Test Gains	
			Special Chemistry	Anderson-Fisk Chemistry
1	24	16	7	2
2	33	22	6	14
3	30	20	8	4
4	21	14	12	5
5	19	17	7	4
6	23	20	6	12
7	19	15	2	4
8	19	19	2	3
9	31	15	11	4
10	32	20	17	8
11	24	21	6	11
12	33	17	16	13
13	27	19	12	2
14	26	22	14	5
15	26	19	10	10
16	24	12	7	1
17	30	24	11	14
18	16	14	4	5
19	29	16	10	11
20	34	24	9	15

Control Group

21	21	19	6	5
22	23	25	3	10
23	26	20	7	5
24	19	12	4	-1
26	35	34	14	14
27	26	31	16	11
28	26	27	8	13
29	26	26	8	9
30	30	20	8	7
31	20	20	3	7
33	11	23	-5	8
34	24	21	10	-1
35	19	25	6	19
37	33	36	9	16
38	28	35	6	17
39	26	22	4	2

41	23	28	5	12
42	27	29	-1	11
43	32	44	4	28
44	16	25	2	13
45	27	36	15	23
46	21	21	12	10
47	22	24	2	7
48	30	36	15	22
49	32	31	11	11
50	30	24	15	18
51	20	20	7	1
52	22	20	1	3
53	18	16	4	9
54	20	18	8	3
55	24	23	5	7
56	19	16	1	5
57	28	23	13	5
58	30	16	9	4
59	27	34	11	16
60	25	21	3	12
61	23	20	4	0
62	20	25	-3	5
63	31	42	3	16
64	20	20	0	4
65	22	19	5	11
66	27	29	3	16
67	17	19	1	9
68	18	15	-3	6
69	28	31	6	24
70	15	21	-5	4
71	21	18	0	6
72	16	23	3	8
73	24	15	3	12
74	16	15	-4	-2
75	17	17	2	8
76	37	33	7	18

APPENDIX F

CORRELATIONS (Pearson Product-Moment)

		r Group	
		Experimental	Control
Pre vs Post Tests:			
I	Special Chemistry Pre vs Special Chemistry Post	.66	.47
II	Anderson-Fisk Pre vs Anderson-Fisk Post	.14	.43
XXIX	Special Chemistry Pre vs Anderson-Fisk Post	.46	.34
XXX	Anderson-Fisk Pre vs Special Chemistry Post	-.24	.27
Pre-Test Correlations:			
III	Reading Total (X2) vs Special Chemistry Pre	.65	.13
V	Reading Total (X2) vs Anderson-Fisk Pre	-.17	.21
VII	Verbal Reasoning vs Special Chemistry Pre	.70	.23
IX	Verbal Reasoning vs Anderson-Fisk Pre	-.34	.18
XI	Numerical Ability vs Special Chemistry Pre	.51	.33
XIII	Numerical Ability vs Anderson-Fisk Pre	-.30	.12
XV	Abstract Reasoning vs Special Chemistry Pre	.54	.32
XVII	Abstract Reasoning vs Anderson-Fisk Pre	-.27	.22
Post-Test Correlations:			
IV	Reading Total vs Special Chemistry Post	.56	.44
VI	Reading Total vs Anderson-Fisk Post	.63	.48
VIII	Verbal Reasoning vs Special Chemistry Post	.64	.50
X	Verbal Reasoning vs Anderson-Fisk Post	.58	.42
XII	Numerical Ability vs Special Chemistry Post	.62	.33
XIV	Numerical Ability vs Anderson-Fisk Post	.36	.48

XVI	Abstract Reasoning vs Special Chemistry Post	.53	.46
XVIII	Abstract Reasoning vs Anderson-Fisk Post	.41	.60
XXXXVII	*Sum 3 vs Special Chemistry Post	.63	.51
XXXXVIII	*Sum 3 vs Anderson-Fisk Post	.60	.60
XXXXIX	Reading Total plus DAT Total plus Special Chemistry Pre vs Special Chemistry Post	.66	.54
XXXXX	Reading Total plus DAT Total plus Special Chemistry Pre vs Anderson-Fisk Post	.63	.58

Gain (Post-Pre Special Chemistry) Correlations:

XIX	Reading Total vs Special Chemistry Gain	.05	.35
XXI	DAT Total vs Special Chemistry Gain	.18	.26
XXIII	Verbal Reasoning vs Special Chemistry Gain	.10	.33
XXV	Numerical Ability vs Special Chemistry Gain	.28	.06
XXVII	Abstract Reasoning vs Special Chemistry Gain	.13	.21

Gain (Post-Pre Anderson-Fisk) Correlations:

XX	Reading Total (X2) vs Anderson-Fisk Gain	.60	.37
XXII	DAT Total vs Anderson-Fisk Gain	.67	.51
XXIV	Verbal Reasoning vs Anderson-Fisk Gain	.69	.33
XXVI	Numerical Ability vs Anderson-Fisk Gain	.50	.44
XXVIII	Abstract Reasoning vs Anderson-Fisk Gain	.51	.49

XXXI	*Sum 3 vs Special Chemistry Gain	.10	.33
XXXII	*Sum 3 vs Anderson-Fisk Gain	.71	.55
XXXIII	Reading Total (X2) plus DAT Total vs Special Chemistry Gain	.11	.34
XXXIV	Reading Total (X2) plus DAT Total vs Anderson-Fisk Gain	.66	.45
XXXV	Reading Total (X2) plus DAT Total plus Special Chemistry Pre vs Special Chemistry Gain	.09	.30
XXXVI	Reading Total (X2) plus DAT Total plus Special Chemistry Pre vs Anderson-Fisk Gain	.66	.46

XXXVII	Reading Total (X2) plus Abstract Reasoning vs Special Chemistry Gain	.67	.18
XXXVIII	Reading Total (X2) plus Abstract Reasoning vs Anderson-Fisk Gain	-.20	.23
XXXIX	Reading Total (X2) plus 2X (Abstract Reasoning) vs Special Chemistry Gain	.67	.21
XXXX	Reading Total (X2) plus 2X (Abstract Reasoning) vs Anderson-Fisk Gain	-.23	.24
XXXXI	Reading Total (X2) plus Numerical Ability plus 2X (Abstract Reasoning) vs Special Chemistry Gain	.68	.24
XXXXII	Reading Total (X2) plus Numerical Ability plus 2X (Abstract Reasoning) vs Anderson-Fisk Gain	-.24	.24
XXXXIII	Special Chemistry Pre vs Special Chemistry Gain	-.18	-.38
XXXXIV	Special Chemistry Pre vs Anderson-Fisk Gain	.50	.21
XXXXV	Anderson-Fisk Pre vs Special Chemistry Gain	-.10	.09
XXXXVI	Anderson-Fisk Pre vs Anderson-Fisk Gain	-.69	-.22

*Sum 3 = Reading Total plus DAT Total plus Special Chemistry Pre plus Anderson-Fisk Pre

APPENDIX G

T-TEST SCORES

	$\Delta \bar{X}$	% Gain	t	A
I Special Chemistry Pre-Test vs Post-Test				
(A) Experimental Group	8.850	51.6	3.960	$< 0.1\%$
(B) Control Group	5.135	27.5	4.985	$< 0.1\%$
II Anderson-Fisk Chemistry Pre-Test vs Post-Test				
(A) Experimental Group	7.350	67.1	3.708	$< 1\%$
(B) Control Group	9.730	66.8	5.886	$< 0.1\%$
III Special Chemistry Gain vs Anderson-Fisk Chemistry Gain				
(A) Experimental Group	1.500		1.160	$< 20\%$
(B) Control Group	4.519		3.902	$< 0.1\%$
IV Special Chemistry Pre-Test vs Anderson-Fisk Chemistry Pre-Test				
(A) Experimental Group	6.200		3.116	$< 1\%$
(B) Control Group	4.115		4.172	$< 0.1\%$
V Special Chemistry Post-Test vs Anderson-Fisk Chemistry Post-Test				
(A) Experimental Group	7.700		3.731	$< 1\%$
(B) Control Group	0.480		0.621	$> 20\%$
VI DAT Total Score, Experimental Group vs Control Group	12.48		2.382	2%
VII Reading Test Total Score, Experimental Group vs Control Group	27.20		2.888	$< 1\%$
VIII Special Chemistry Pre-Test, Experimental Group vs Control Group	1.523		1.297	$> 10\%$
IX Anderson-Fisk Chemistry Pre-Test, Experimental Group vs Control Group	3.608		3.105	$< 1\%$